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ELECTRICAL INDUSTRIES IN ST. LOUIS.

Address by Francis E. Nipher, Retiring President of the Engineers' Club of St. Louis.

[Read December 17th, 1890.]

It seems appropriate at this time to give a brief account of the progress and present condition of electric industries in our city.

The first commercial lighting that might fairly be called successful, was inaugurated by Charles Heisler in 1878 at Conrad's brewery. Alternating currents were used in operating arc lamps. Later he adopted a series system of incandescent lighting, still using alternating currents.

In England the general impression still seems to be that incandescent lamps cannot be successfully operated on long lines without the use of converters and an alternating multiple system. Such was the general opinion in this country until Mr. Heisler pushed boldly into the fieid and finally operated 50 miles of line wire from one dynamo. The Heisler Company, of this city manufacture only central station plants, of which about 70 have been established. The largest plant of about 5,000 16-candle lamps, is operated by the Municipal Electric Lighting Co. in this city. The total capacity of the plants established by this company is about equivalent to 60,000 16-candle lamps. These lamps require 5 amperes, 14 volts, and are said to yield 32 candles with a life of 600 hours.

The Municipal Electric Light and Power Co., which began street illumination May 1, 1890, are now operating 3,300 arc lamps of the Wood pattern, each lamp requiring 9.6 amperes, 47 volts. Of these lamps 1,400 are furnished to private customers.

These lamps are operated in 61 circuits, the longest of which is 21 miles and carries 60 lights. The total length of the lines is about 1,000 miles, the most distant lamps being 10 miles from the power house. The company has 70 60-light and 12 30-light dynamos of the Wood-Gramme pattern, furnished by the Fort Wayne Co. The area covered by their lines is about 50 square miles and the area actually illuminated is about 30 square miles. The power is furnished by six 600 horse power engines and six high speed engines of about 75 horse power. The total energy output of the plant is about 36,000 horse power-hours per day.

The steam supply system is in duplicate throughout. Independent of this double system of steam supply is an independent connection for 1,500 horse power to be used during the day when the loads are light.

The same company operates a Heisler incandescent plant, developing the equivalent of 5,000 16-candle lamps on 150 miles of line wire. At this station four high speed engines are used, with a total capacity of 700 horse power.

The Laclede Gaslight Co. also operate a Heisler plant of 814 32-candle lamps, each requiring 5 amperes, 14 volts. These lamps are used in alley lighting. These are operated in four circuits from two dynamos, of which the longest line is 26.5 miles; the shortest 16.1 miles. The total length of the four circuits is 86.4 miles and the area lighted is four square miles. For indoor lighting, the Laclede Co. operate a Brush alternating system with converters, of which the longest line is 14.1 miles. These circuits are also four in number with a total length of 35.3 miles. The system employs 41 converters with a capacity of 1,245 16-candle lamps.

The power is obtained from two triple expansion Williams engines, having each a capacity of 250 horse power, and one single cylinder Westinghouse engine of 45 horse power.

There are in all at this plant two 1,000-light, three of 900-light and one 650-light dynamos, making a total capacity of 5,350 lights.

The Missouri Electric Light and Power Co. began operations Aug. 1, 1889, operating the Westinghouse system. They now have about 1255 converters in use as follows:

100	10-light converters	1,000	Lights.
500	20-light "	10.000	"
250	30-light "	7,500	"
400	40-light "	16,000	"
5	100-light "	500	"
		35,000	

In November, 1890, the average number of lamps in operation during lightest loads was 3,000 16-candle lamps. During heaviest loads the number was 16,000 or not quite half the capacity. There are now 20 feeders leading from the station, the longest of which is five miles in length. There are eight 3,000-light dynamos, each capable of delivering 150 amperes at 1,000 volts terminal potential, and an additional dynamo of the same capacity will be added during the present month.

The Missouri Company also operate 150 miles of alley lamps, requiring about half the capacity of one of the dynamos. These lights are run in a series-multiple system, twenty 50-volt lamps being connected in series between mains at a potential difference of 1,000 volts. There are 700 of these lights on 35 lines, between three mains, and covering an area of about 12 square miles.

There are now in operation eight 300-horse power Westinghouse engines, seven of which are required at the time of heaviest load, when the indicated horse power was in November last, on the average about 1650.

During July, 1890, the indicated horse power hours per day was 11,040 and during the following November it was 19,800.

There are about 50 isolated electric lighting plants in St. Louis, having in all about 27,000 lights, and representing about 2,700 horse power. The cost of these plants is on the average $9 per lamp, or $243,000. Of these plants 38, representing 22,135 lamps, have been installed by the Edison Co. The largest plants are the Edison plant in the Exposition building, which has 5,000 lamps, and the United States plant at the Custom House, which has 1,930 lamps.

The Union Depot Railroad Co. are now operating fourteen miles of double track by electricity, using a Thomson-Houston plant. At present eight compound dynamos are in use, each capable of delivering 150 amperes at 500 volts terminal potential. When complete, twenty-two dynamos will be used, making 2,200 horse power in all.

At present 24 motor cars are run during light traffic and 34 motors and trail cars are used during the heavy traffic in morning and evening. The number of cars will be considerably increased in the near future in order to provide for the increasing traffic.

During heavy traffic with 34 cars the power required is at the rate of 10 horse power per car, and during light loads the power required is 6 horse power per car. The number of horse power hours per day is about 7,350.

The plant is supplied with four Hamilton-Corliss engines with rated capacity of 250, 350 and two of 500 horse power. At present one 500 horse power engine will operate the entire road.

The Lindell Railway Company are also introducing the use of electricity. At present 22 cars are being operated by electricity, and in a few days the entire road of about 33 miles of single track will be in operation. It is reported that when completed the number of cars will be 67. I was however, unable to obtain any definite information concerning the operations of this road.

It is interesting to turn from such extensive and important industries involving the outlay of millions of dollars and furnishing employment to an army of men, to the humble and unobtrusive beginning of all these splendid things.

On Sept. 22, 1831, Faraday wrote in his laboratory note book as follows: "I have had an iron ring made (soft iron), iron round and ⅞ of an inch thick, and ring six inches in external diameter. Wound many coils of copper round, one half of the coil being separated by twine and calico. There were three lengths of wire, each about 24 feet long, and they could

be connected as one length or as separate lengths. By trial of a trough, each was insulated from the other. We will call this side of the ring A. On the other side, but separated by an interval, was wound wire in two pieces, together amounting to about 60 feet in length, the direction being as with the other coils. This side call B.

Charged a battery of ten plates, four inches square, made the coil on B side one coil and connected its extremities by a copper wire passing to a distance and just over a magnetic needle (three feet from wire ring.) Then connected the ends of one of the pieces on A side with the battery; immediately a sensible effect on needle. It oscillated and settled at last in original position. On breaking connection of A side with the battery, again a disturbance of the needle."

Later he varied the experiment and writes:

"In place of the indicating helix our galvanometer was used, and then a sudden jerk was perceived when battery communication was *made* and *broken*, but it was so slight as to be scarcely visible. It was one way when made and the other way when broken, and the needle took up its natural position at intermediate times."

The device which Faraday describes was a transformer. The impulses which he saw in the needle were due to induced currents. He was at once led on to the invention of the first dynamo, which he constructed during the same month. But if any person had asked Faraday what practical use could be made of his discovery, he would have been utterly unable to make a satisfactory reply. The effects were so small that it was with difficulty that they could be seen. The forces were utterly insignificant. Who would then have imagined that these feeble impulses would some day be pumped through wires to light large cities and to move heavy cars loaded down with passengers? Who would have believed that articulate speech would ever be transmitted by them? Had any prophet fortold all this at that time, it would have been called the idle fancy of a useless brain. And yet these great things at once became possible when Faraday made those simple experiments. They have all followed directly from these discoveries. Probably nothing since the invention of the wagon wheel is destined to have a more profound effect upon the civilization of mankind.

At the present time the proposition to illuminate a large city by electricity would hardly be considered the dream of an enthusiast. It would be hard now to find an intelligent man so conservative that he would pronounce such a plan commercially impossible.

Eleven years ago eminent gentlemen who were in a position to know most about the merits of the project, and who were anxious to avoid making mistakes; who were also anxious (for a consideration) to prevent people from making foolish investments, were nearly all of an opposite opinion. Dynamos had indeed been built in abundance, but they could not be depended upon to maintain even the few lamps which they operated. The light was fitful, the service was uncertain. Something was always going wrong; and as for the enthusiasm which was everywhere manifest among the people, and the proprietors of dynamo machines, it was pointed

out that forty years before the inventors had precipitated a similar period of crazy excitement, and nothing had come of it.

It is certainly a bad omen if those who are in a position to know most about any project, pronounce it a hopeless case. They are generally right. In that event they seldom get credit for their wisdom, and the promoters of the schemes which they properly extinguish are always left with a feeling that the failure was due to the opposition of those who should have given support.

But the judgment of the competent is sometimes at fault and it was so in the matter of municipal electric lighting. It was left to men whose knowledge of the difficulties to be met was so limited that they were not aware of the magnitude of the problem, to do most of the drudgery and bear the burdens of the pioneer work.

Nor were these difficulties believed to be wholly of a kind that could be overcome by the ingenuity of man. The distinguished electrician of the English post service, now a well-known electrical engineer, Mr. W. H. Preece, in the January number of the *Philosophical Magazine* for 1879, gave a mathematical discussion of the problem of electric lighting. In this paper he showed, apparently to the satisfaction of everybody, that we were struggling against a law of nature. Mr. Preece assumed a given dynamo or battery having a limited or fixed electro-motive force. He assumed lamps to be connected either in series or in multiple. As the number of lamps increased, he showed that in either case the system soon approached and reached a condition where the power that could be expended on the lamp system would vary inversely as the number of lamps. The power expended in each lamp would then vary inversely as the square of the number of lamps.

This state of affairs is brought about in the series system, by the condition that the resistance of the lamp system is directly proportional to the number of lamps. The increasing resistance enfeebles the current. When the resistance of the lamp system has become so large that the dynamo resistance is inappreciable, then the effect of doubling the number of lamps is to divide the current by two. The current enters to the second power in the expression for electrical energy, so that energy and power per lamp are divided by four.

On the other hand, in the multiple system, an increase in the number of lamps diminishes the resistance of the lamp system. When this resistance becomes insignificant compared with that of the dynamo, the power is all expended in heating the dynamo. Mr. Preece gave the electric illuminators a parting blow by saying that the case was even worse than he had painted it, as he had said nothing of the power wasted in the conductors, or the heat required to bring the carbons up to a temperature of incandescence. He concludes as follows:

"We have assumed W (the total power of the dynamo) to be constant; but this is only the case when a certain limit is reached, and when the velocity of the rotating coils in the dynamo machine has attained a maximum. This limit will vary with each dynamo machine, and each kind of lamp used. With the Wallace-Farmer machine the limit appears to

be reached when six lamps are connected up in series. With the Gramme alternating machine and Jabloschkoff candles, the limit appears to be five lamps. Beyond these limits the above laws will be true. It is this partial success in multiplying the light, that has led so many sanguine experimentors to anticipate the ultimate possibility of its extensive subdivision,—a possibility which this demonstration shows to be hopeless, and which experiment has proved to be fallacious."

These conclusions obtained wide currency for about a year. While reading the paper of Mr. Preece with a view of making an exposition of the matter in a lecture, it occurred to me that the conditions assumed by Mr. Preece were not necessary—that, in fact, a series-multiple arrangement of lamps might be made and the resistance of the lamp system thus made independent of the number of lamps. It also seemed to me that dynamos might be coupled in multiple or in series, and although I then wrote the equations and drew the efficiency curves for such a plant, I did not publish the results. I had had no practical experience with dynamos, and was not sure that they would operate when connected together like battery cells.

The publication of the series-multiple arrangement for a lamp system put an end to the idea that had gained currency on the publication of Mr. Preece's paper. The system of alley lighting used by the Westinghouse company in this city, is, so far as the arrangement of lamps is concerned, exactly the one which was shown to be possible in my paper of Dec. 31, 1879.

As we now look back on the crude ideas that we all held in the early days of electric lighting, it seems incredible that so much labor, and such vast sums of money should have been expended in learning what seems so plain and simple now.

There was no error in the equations of Mr. Preece. His conclusions seemed to be justified by what was then known, but as Mr. Huxley has said, "the grist one gets from a mathematical mill, depends upon what one puts into it." The fact is we are doing exactly what Mr. Preece said was hopeless; but in a somewhat different way from the ones then in his mind. We have self-regulating dynamos, which within certain limits will maintain constant currents through the lamps as lamps are switched in and out; and the capacity of dynamos is now ten times as great as in 1879. Still these dynamos can be overloaded, and they will then behave just as Mr. Preece said they would. On account of the increased capacity of dynamos it is not as serious a matter as Mr. Preece thought it would be to finish the task by the duplication of dynamos.

During the whole progress of the electrical industry, it has been most instructive to see how some new improvement has sometimes changed the whole aspect of affairs, as when reserve troops are thrown into a doubtful contest. Plans and machinery which the prudent and conservative engineer had decided to be valueless, came then to the front, and the struggle of contending interests began on new ground and along new lines.

For example, Faraday invented the transformer or converter in 1831. It was an iron ring upon which his primary and secondary wires were

wound. Ruhmkorff and Ritchie in their well-known induction coils, showed how to convert a large current of low potential into a small current of high potential, and at the same time used a laminated core composed of a bundle of iron wires.

Then it was discovered that the induction coil is reversible, and that a small current of high potential can be converted into a large current of low potential.

It is interesting to observe that in 1883 the U. S. Patent Office refused a patent to Bernstein for a converter, on the ground that he could not possibly get out of the converter on the secondary wire, a larger current than he put into it on the primary. In 1886 the same office gave Gaulard and Gibbs a patent for the same device,* the impossible having meanwhile become possible. Then came the great step of placing the iron around the primary and secondary coils, instead of within them. This was what brought it to the front as the powerful ally of the alternate current dynamo which then became the formidable competitor of the secondary battery.

In a similar way the work of Dr. Wellington Adams of this city on the equipment of electric motor cars brought about a complete revolution in their construction. When his paper read before this club April 23, 1884, was published, the building of electric locomotives like those of Siemens and Edison wholly ceased. The entire subsequent development of the electric railway has proceeded along the lines which Dr. Adams laid down. The application of the power directly to individual car axles, centering the motor and its gearing upon the axle, so that different axles may move independently without deranging the gearing, the provision for the oscillation of the field on the car axle as an axis, while held in position by elastic resistance, all this was first done in our city, and was first proclaimed to the public by Dr. Adams in a meeting of this club.

Over and over again have we learned that we should have a watchful eye upon those things which have no practical value. Students and engineers alike are prone to ignore with systematic deliberation, those things which have no commercial value. But the history of scientific discovery and of engineering progress is simply a history of the work of men who applied their brains to useless things and made them useful; who successfully did what had been considered hopeless or had been overlooked as worthless.

In Compte's Positive Philosophy a rather positive statement is made to the effect that while the forms and distances of the heavenly bodies might be determined, "we can never know anything of their chemical or mineralogical condition." What Compte doubtless had in mind was that chemists would never get their hands on any samples of these bodies for treatment in test-tubes. But something unexpected happened. Physics came to the aid of chemistry, and star analysis became possible without the necessity of carting specimens to Paris.

It must be confessed, however, that this kind of work—the doing of

*Thompson's Dynamo electric Machinery.

"impossible" things — is not for all men. Within rifle shot from this place there are men who are trying to execute the plan, of driving a dynamo by a steam engine the steam for which is to be produced from heat developed by the driven dynamo. No amount of explanation can make such people understand why this is impossible, or that the combination would be absolutely devoid of commercial value, even if it could be made to succeed to perfection.

Nor do I wish to ignore the fact that the commercial instincts of mankind should be considered, in deciding what is to be undertaken. No company of business men should be willing to expend all of their capital in convincing themselves that the undertaking might have succeeded, if they had had a few more millions of capital and a few hundred years of time.

It is not an easy thing to draw the line between the cranks and the engineers. Different people draw the line in different places. It is a matter of individual judgment. Time and the march of events have frequently made it necessary to revise or reverse such judgments. We pass by imperceptible stages from the well-marked engineering lunatic, who is trying to make an engine or a dynamo drive itself, and who seems to have an idea that it will also be able to drive anything and everything else in the universe that needs driving, to the man who believes he can operate street-cars or illuminate great cities by electricity; that he can telegraph through ocean cables and drive ships and railway cars by steam.

Fortunately or unfortunately, men do often make mistakes in deciding what they should undertake. They spend their lives or their fortunes in trying to do things before the times are ripe, and while the difficulties are too great. They achieve only a partial success, which commercially is no success, and those who follow them, enjoy the benefits of their labor, and finally not only reap the pecuniary reward but monopolize all of the glory.

The data concerning the electric plants has been kindly furnished by Messrs. Emerson McMillen of the Laclede Gas Light Co., John Scullen of the Union Depot Railway Co., S. M. Dodds of the Missouri Electric Light and Power Co., and James I. Ayers of the Municipal Electric Light and Power Company. Mr. E. F. Horn, Agent of the Edison Co. furnished most of the data concerning isolated plants. To all of these gentlemen I am indebted for many courtesies. F. E. N.

LAKE CURRENTS, AND PROPOSED OPENING OF THE BREAKWATER.

By Walter P. Rice, Member of the Civil Engineers' Club of Cleveland.

[Read September 9, 1890.]

As has been remarked by Mr. L. E. Cooley, "The physics of the lakes have never been adequately studied, and it is a profoundly interesting field for research." The writer, having had the benefit of some years of observation on the lake, and having made special examinations for both the U. S. Government and the City, has been induced to write the following paper in the hopes of bringing out a discussion and attracting attention to a neglected field.

I believe the causes which produce currents may be summed up as follows:

I. The winds.
II. Variation in atmospheric pressure.
III. Natural flow of the lake.
IV. Difference in temperature.

Causes I. and II. when acting in concert would produce strong currents, and I believe offer sufficient explanation of phenomena which have long puzzled scientists and which the press have termed "tidal waves;" but as this same public educator has, since my recollection, blindly and persistently insisted on calling tornadoes—cyclones until the general public is no longer able to distinguish. I have some doubts as to whether I am using the right nomenclature.

Currents due to causes III. and IV. are, I think, of lesser strength and subservient to those caused by I. and II.

STRENGTH OF LAKE CURRENTS.

D. Farrand Henry has observed a current of at least three miles per hour in the open lake in Lake Superior.

The experiments at Cleveland indicated surface currents varying from one-eighth to two miles per hour, and middepth currents varying from one-tenth to one and three-fourths miles per hour.

Mr. L. E. Cooley stated to me that the investigations at Chicago by Rudolph Hering and himself, while never fully digested or published, indicated currents due to wind in Lake Michigan of greater intensity than the above. Mr. Cooley also states having found currents across the lake from Chicago in 250 feet of water usually of less than one-half mile per hour.

EXPERIMENTS AT CLEVELAND.

As these experiments have been fully described in a report to the Sewer and River Commission, I will recapitutate as briefly as possible. A base line was established with stations located near the East Pier, at Alabama street, and near East Madison avenue, and having telegraphic communication thus rendering observations practically simultaneous.

Spar buoys were established at 1, 2, 3, 5 and 10 thousand feet distances

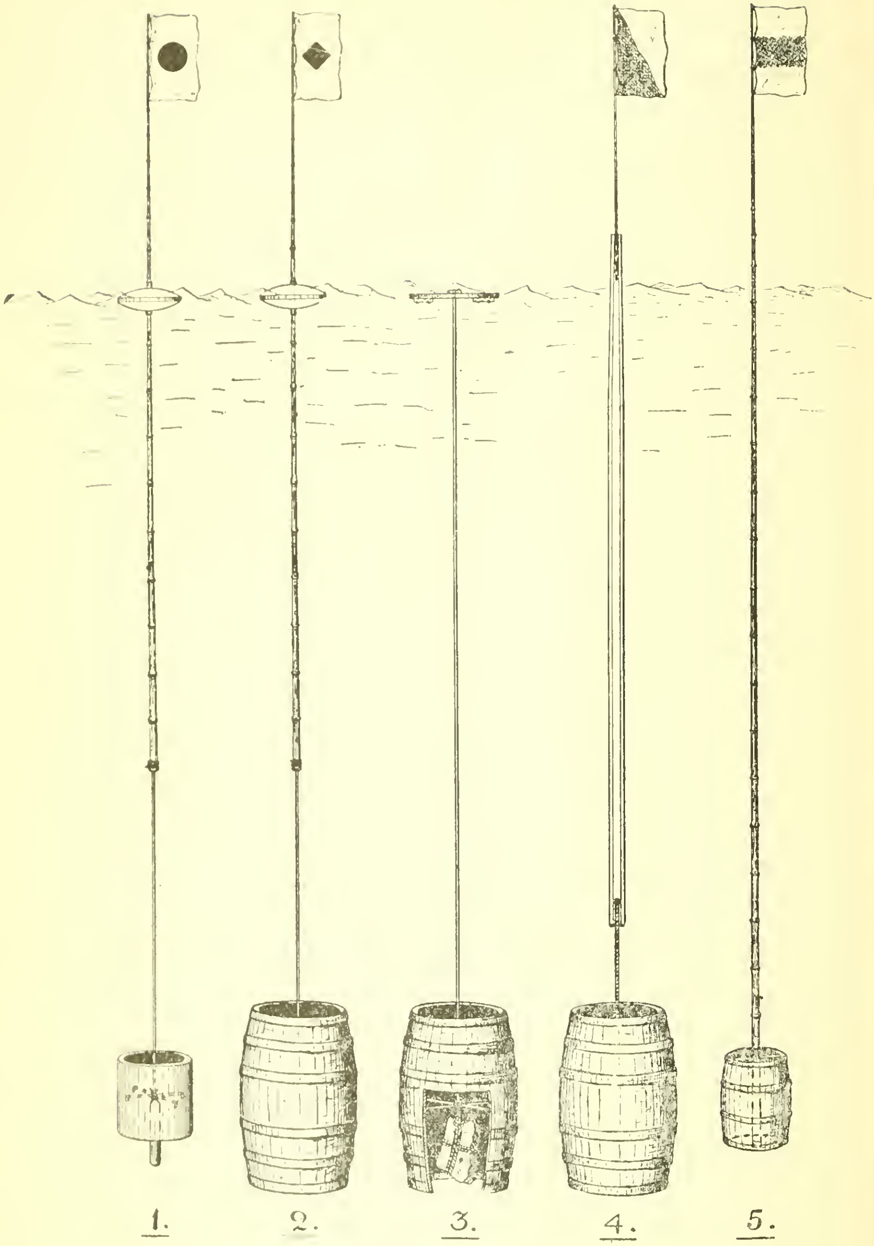

PLATE NO. 1.

from the shore in prolongation of both Muirison and Marquette streets. As a general rule two floats were released at each buoy, one for surface and the other for middepth currents; the movements and positions of same were noted from time to time by triangulation.

The *surface float* consisted of a four foot cedar post carrying a small flag and weighted with stone.

The *middepth* float finally adopted consisted of a pole float, with submerged oil barrel, having the heads knocked out and sunk by means of weights attached to a couple of cross rods at the center of figure, as shown by Fig. 4.

Fig. 4 having more surface exposed to wind than Fig 3, experiments were made to ascertain the amount of error due to same. Very little difference was noted in the results, although there must of necessity be some error due to this cause tending to give velocities somewhat in excess of the true ones. The middepth observations are, in my opinion, the most reliable, as I believe in this case as with a river the suspended float that is nearest the region of mean velocity gives a more correct "velocity measure than any other point of the stream section."

As it was early discovered that the observed currents were under control of the winds all velocities were expressed as a per cent of the latter. The results were as follows:

Surface currents from 1,000 to 10,000 ft. lakeward run from 7 to 5% up lake, and from $3\frac{1}{3}$ to $3\frac{1}{10}$ down lake.

Middepth currents run from $2\frac{56}{100}$ per cent. to $5\frac{6}{10}$ per cent. up lake, and from $2\frac{33}{100}$ per cent. to 2% down lake.

Surface—average per cent. up stream, 6.03%; down stream, 3.54%.

Middepth—average per cent. up stream, 3.893%; down stream, 2.071%.

It will be noted that the unexpected relation between up and down lake currents practically holds good for both surface and middepth currents, the effect up the lake being about double that down the lake.

A few observations taken off the mouth of the river near opening of breakwater reversed the foregoing results and showed a greater effect *down* the lake, the percentage being as follows:

Middepth currents, $1\frac{4}{10}$ per cent. up lake; $2\frac{4}{10}$ down lake.

This harmonizes with the results I obtained in an experiment made off the ends of the pier before the construction of the breakwater with the annular submerged float of Gen. Ellis, and can, I think, be accounted for by the unexpended river current.

As has been mentioned in a previous report, the topography of the south shore of Lake Erie shows a straight coast line, broken by one indentation or pocket, the most southerly point of which marks the location of the City of Cleveland. The general coast line prolonged would pass 7 miles out to sea. The city is so situated as to have two-thirds of the lake to the east and one-third to the west; this affording double the length of sea for winds blowing from the easterly half of the compass. To my mind this fact principally accounts for the increased strength of currents up the lake, although Mr. Whitelaw's eddy may be a more important factor than I have given it credit for in this instance.

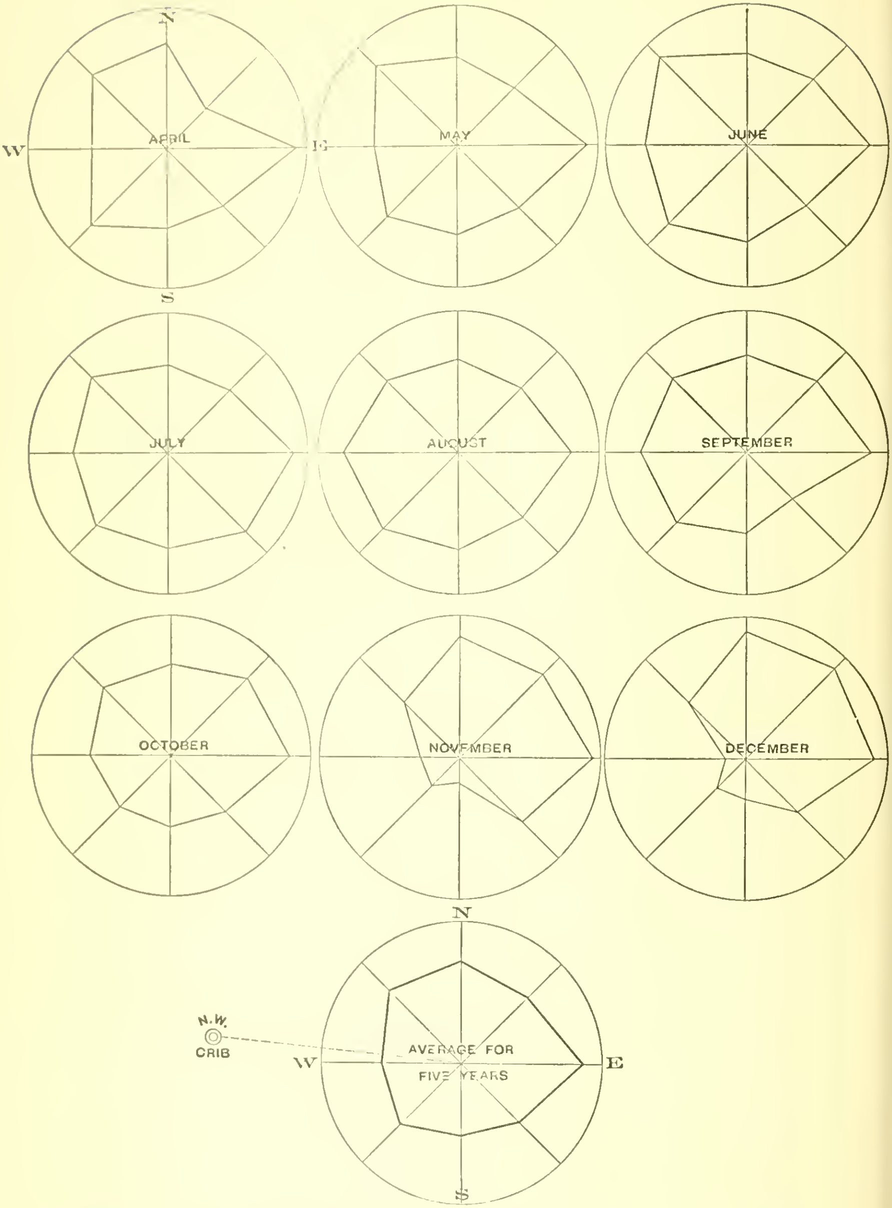

PLATE NO. 2. Graphical illustration showing the movement of the winds at Cleveland, Ohio, from 1883 to 1887 inclusive.—Scale 3350′ to 1″.

The currents due to the winds are so much stronger than the current due to the natural eastward flow of the lake that I consider the latter a homeless wanderer in search of the path of *least resistance*, and like the ancient king in fear of assassination, occupying a different bed on every night.

A rough estimate of the mean velocity of flow of a section of the lake opposite Cleveland would be eight-tenths feet per minute, while the average of the middepth velocities observed was 19 feet per minute. Also it is a well known fact that large variations in the discharge of the St. Clair and Niagara Rivers are caused by winds. If the value of lake currents due to wind were expressed by formula, I believe the principal factors would be those of velocity, time, and length of sea.

Prof. Zoppritz attempts to formulate the physical problem of the propagation of surface velocities downwards through a thick stratum of water on the theory of the friction of fluids.

With the coefficient of friction (as determined by Meyer), he arrives at the following result with regard to ocean currents:

"That for a layer of water 100 meters deep to assume one-half the surface velocity would take 239 years." He further remarks the same velocity will be attained at a depth of 10 metres in 2.39 years; his reasoning indicating a rate of propagation of extreme slowness.

This certainly is not the case on the lakes, where the conditions are different, and where, as Rudolph Hering remarks, "in water of moderate depth the currents go substantially with the winds" and *respond quickly* to any change.

The effect of atmospheric disturbances would be more marked in case of an extremely shallow body of water like Lake Erie.

In my opinion the strongest currents due to regular forces would be developed under the following circumstances: A gale or blow of *long duration* lengthwise of the lake followed by a sudden cessation of wind. In other words, the head of water produced by the accumulation or heaping up on lee shores (in amount sometimes four feet and over) is a direct measure of the current intensities and the *time* occupied in creating the head being probably greater than the *time* occupied by its dispersion the return or readjusting currents would be of maximum strength.

THEORY OF CURRENTS.

In attempting to apply mathematics to such currents as are induced by the winds, the natural reasoning would lead to the assumptions first of a constant wind force acting on the surface, second of an infinite number of horizontal strata, and the gradual propagation of an initial force at the surface downward, the friction of the wind setting the surface stratum in motion, this in turn dragging the next stratum, etc. Practically, however, every irregularity of the bottom, or the shores, the interference of works of construction and entrance of tributaries modify the theoretical assumptions. So there will be longitudinal currents, lateral currents, vertical currents; in fact, I am inclined to think currents in every conceivable plane. Generally speaking, any analysis of the subject except in

a general way is so difficult that I doubt if it will ever be solved unless by some erudite German professor of engineering, and I think very few of the ablest hydraulicians would be willing to stake their reputations as to the exact results in every particular of interference with laws of this kind by works of construction; certainly many failures are recorded by the brightest minds in this direction.

It will therefore be premised from what I have said that not wishing to "rush in where angels are shaky" what I have to say about the proposed opening of the west arm of the Cleveland breakwater will be in a very general way.

The following data is available for a discussion of this kind.

First.—The effect of the winds in the production of currents (which I think has been clearly shown).

Second.—The character of the wind movements. (For the use of the club I have submitted a graphical illustration of the average wind movement (time by velocity) at Cleveland for a period of five years, the months of January, February and March being excepted).

Third.—The well known law that all movement of the shingle or sand is up or down the shore, and that constructions, more or less, normal to the shore offer a nucleus for its detention.

Fourth.—The fact that under conditions of quiet the confined water of the Harbor of Refuge acts as a wall or bank for the guidance of the river.

Fifth.—The existence of an eddy in the vicinity of the breakwater.

From the above and other data I would hazard the following conclusions: That if an opening were made in the shore arm it would somewhat decrease the amount of deposit in the southwest corner; so would the cutting off of the northeasterly seas, although to, perhaps, a less extent.

It is evident that the circulation through the breakwater would purify the same and send the sewage and pollution out into the grasp of any malicious eddy that might be lurking in the vicinity. With regard to deposit in the breakwater near and due to the Cuyahoga (the heavier deposits I mean) I do not believe that dredging bills would be reduced on account of proposed opening.

DISCUSSION.

MR. WHITELAW:—My interest in this discussion centers entirely in protecting the water supply of the city.

The purpose of the opening of the west arm of the breakwater is simply to allow the flow of the water upward in the lake.

I have discovered, and perhaps a good many others have, that the indentation in the shore line creates an eddy in the lake, carrying a portion of the river water westward. Almost everyone familiar with the lake has noticed that there is a colored streak of water running outside the outer arm of the breakwater, that comes with freshets; when the lake is not much disturbed this line can be distinctly seen. The building of the breakwater has thrown the eddy out in the lake further. The number of times that the water in the intake of the crib has been found charged with

river water is very much greater than before the breakwater was built.

In the winters of 1869 and 1870 I spent a great deal of time on the ice making observations to trace the taste of petroleum in the water for a distance of three miles west of the river. I found that 4,300 feet from shore was the outer limit at which anything of that kind could be observed, and the distance seemed to be pretty uniform. In 1865 or 1866 the taste of petroleum got into the lake water furnished to the city from the old inlet, which was 300 feet from shore, and it was assumed, and the city acted on the assumption, that the reason of this was that a dam of ice had formed across the mouth of the river and along the bar a few hundred feet out from shore, westward to the intake, and action was taken to break the ice and let the river water run out. That same current prevails when there is nothing of this kind. That fact I established by the observations made in 1869 and 1870.

The shore line here makes such a difference in the current of the lake that it seems strange that it has been overlooked in the reports on the current.

MR. J. H. SARGENT.—The situation of Cleveland, at the widest part of Lake Erie and the formation of the coast line to the west and the east of it leads me to expect at this point, counter currents, or currents tending westward. The cross section of the waters of the Lake at this point is so great that the *average* current tending eastward would be hardly perceptible in our Harbor of Refuge even if the shore arm of the breakwater were left off. The quantity of water—if it is not a sin to call it water, discharged by the river, is too small to affect it except in times of a freshet.

If sometime in the future the breakwater with a shore arm at the City Hospital is completed, Cleveland will soon have a *mare clausum* as fragrant as St. Paul's island in the sea of Alaska, after the killing season is over; unless some thing more effectual is done than boring holes or cutting passages through the breakwater.

Let it be remembered that the breakwater is in no sense designed to hold water, but merely to break the force of the waves. In the first place some 1,200 feet of the shore and of the breakwater is merely a pile pier filled in with large stones, and right through this the sand of a considerable beach that once existed west of it, has been carried into the harbor; not only this, but the one and a quarter miles of high earth banks are fast going the same way, in so much that the Lake Shore road is only saved by rip-rap walls of massive stone. The whole breakwater stands upon a loose bed of stone four feet high.

Hence, the idea of cutting a gap through the breakwater to let lake water in or the harbor slush out, is futile.

But to return to the lake and harbor currents. Besides the consideration above referred to, we have the winds, freshets, droughts, and perhaps tides to make these "As variable as the winds," literally.

A southerly wind drives the river slush into the outer harbor, but the river being two hundred feet wide, while the outer harbor is two miles wide, its current is soon dissipated and very little escapes.

As in the winter when the outer harbor and the lake as far out at least

as the crib, is covered with ice, this escape finds its way westward to the water works crib, there must be a westward current even when the water is protected from the winds.

The more openings you make through the breakwater the more you will distribute the slush through the outer harbor. Compensating winds from lakeward can be very little helped by the additional openings, owing to the porosity of the breakwater.

When a freshet comes, the accumulated sewage and sands from the side-runs will be carried forward; the heavier part of this will nearly all be deposited before it reaches the Harbor of Refuge, especially if you give the river two mouths by opening out the old river bed, while the semi-fluids —the most objectionable part of the sewage, will be deposited in the outer harbor. But there is another element insoluble in water, the oils and oily acids and animal floats, that will evaporate and be brought back to us by the air we breathe.

With certain winds and perhaps oftener than otherwise the flow will be out of your western opening on a direct route with an offland breeze, to the intake of the water works cribs.

This might be mainly prevented by extending your breakwater a mile and a quarter west to a point opposite the slate cliffs in, say, twenty feet water with your opening on the shore side of it; and farther, you would protect the wasting banks and make it possible to reclaim a hundred acres of land already wasted away. This would be a sensible thing to do.

But, gentlemen, all this talk of purifying your otherwise beautiful and invaluable Harbor of Refuge by any manipulation of its currents when you have once discharged into it the nastiness of the Cuyahoga river and valley, is futile. The only thing to do is to restore the river to a *water* carrier instead of a carrier of sewage and filth.

This is a simple and easy thing to do. True, it will cost something, but it is for the benefit of the whole people—in fact, a matter of life and death to many, and will not cost as much as your central viaduct, built for the especial benefit of a small section of the city; and it will not cost more to maintain the drainage than to maintain the viaduct.

Mr. Searles.—It seems to me that it will not be many years before what is now called our harbor will be solid land and the present shore line as now marked on our maps will simply be transferred to the line occupied by the breakwater. The arm is already sufficiently near the shore to make it profitable to fill the space up. Improvements are now going on within the harbor which are surely tending to that direction. It may be used as a slip for a while. Eventually it will be used for our large storage ware-houses, etc, and these things must be taken into account in any definite solution of the problem as to how we shall keep our city water pure.

If we had tides here the problem would be entirely different. The currents are so slight as to make a difference in opinion as to which way the currents do flow. It seems to me true, however, that the current is never strong enough to tear up the bottom. On the other hand there is

current enough to carry the filth down the river and distribute it in the harbor.

To my mind there is very little objection to opening the west arm of the breakwater. It is a protection to shipping and against shoaling in case of wind storms coming from one direction only. While by checking all current along shore it causes the water to deposit all the silt brought in by eddies from the river, and the evidences of shoaling are very apparent already.

IN MEMORIAM.

Thomas Jefferson Whitman, C. E., Died Nov. 25th, 1890.

[Engineer's Club of St. Louis, Dec. 17, 1890.]

Our club is again called upon to mourn the loss of one of our charter members, called away so suddenly that some of his oldest friends, hurrying to his bedside on learning of his illness, found crape on the door to tell them they were too late to clasp that kindly hand again.

Thomas Jefferson Whitman was born in Brooklyn, N. Y., on July 18th, 1833, the eighth of a family of nine children. His father was a carpenter and builder, of extraordinary ability, a natural mechanic, noted for the strength and symmetry of his work. From him our friend, no doubt, inherited that straight-forward honesty, and that intuitive mechanical insight which marked his professional life. His mother, descended from the early Dutch settlers of New Amsterdam, was a woman of sympathetic and poetical temperament, in whose kindly face could be traced those pleasant lines indicative of quick wit and humor. From her he must have drawn that fund of geniality, which smoothed over many a rugged path his sterling integrity compelled him to choose.

His elder brother, "the good gray poet," had large part in his early education, and in 1848 carried "Jeff," then a lad of 15, with him on a leisurely journey through all the Middle states, and down the Ohio and Mississippi; no doubt this training enhanced his natural tendency for the poetical in life. Returned to Brooklyn, he was at 16 apprenticed to the printers' trade, but soon left that for land surveying, and when about 20 years old took professional service with an engineering firm largely interested in harbor improvements in New York City. At 23 he became an assistant engineer under James P. Kirkwood in the location and construction of the Brooklyn water works. Under this celebrated engineer he also did duty in the Bergen, N. J., tunnel, and in the construction of the Newburg branch of the Erie railroad. In 1860 and 1861 respectively he was an assistant engineer in the sewer departments of Brooklyn and New York. In 1863 he became chief assistant engineer, under Moses Lane, of the Consolidated Sewer & Water Departments of Brooklyn. In May, 1867, he accepted the position as chief engineer of our St. Louis Water Works, which were constructed under his skillful supervision, his old friend and former chief, James P. Kirkwood, being consulting engineer.

The works were completed and put into service in June, 1871, and with occasional additions to machinery and plant, have served our city for nearly 20 years, and stand today possibly the best designed, best constructed, and most practical system of water works of any large city west of the Alleghenies. There is his monument.

We may not believe that the political "pull" was any weaker, the desire of city contractors for profits less ardent in the 70's than in the 90's; nor were there wanting then, beardless youths, ambitious of journalistic honors, with whom a sensation at the expense of city officials out weighed the ninth commandment. But we rejoice in the thought that here was an engineer able, skillful, thorough and conscientious, who built these works according to true rules, who saw that the city got its full rights under the contracts, whose conduct throughout all obeyed the same plumb and level which he applied to engine and reservoir.

On the adoption of the "Scheme & Charter," Capt. Whitman became the water commissioner of the city, continuing as such by reappointment under successive administrations until three years ago. Since then he has been engaged in an extensive and important practice as consulting engineer. Such works as the Kansas City, Leavenworth, Minneapolis, and Memphis water works have had the benefit of his talents: and the design for a comprehensive sewer system in Milwaukee was among his works during this period.

Like most of the older generation of engineers, Whitman depended less on formulæ and mathematical deductions than on native talent sharpened and instructed by the hard experiences of a life spent in actual construction, and trained to quick action in the face of novel difficulties. One of our former members, whose genial face looks down upon us from its place of honor, himself skilled to chase the elusive "x" through the mazes of a cubic equation, was wont to illustrate this by an anecdote. He had been levelling and cross-sectioning patiently for some days to prove up the best location for a reservoir for a growing southern city—Whitman came up, looked quizzically at the well filled field books, and sauntered leisurely off across the country; in an hour he came back with the positive statement that he had found a better location for the basin. A few measurements by the surveyors proved him correct, and the reservoir was built on the new site for half the estimated cost of the first location.

Who could soothe the overwrought nerves of an expert testing party on constant strain for twenty-four hours, at the concluding breakfast or supper, by a well-told and well-turned story, better than this genial friend? Who better than he could shorten and cap off a long argument by a witty speech which convinced even more than it amused? As an engineer and a public officer his escutcheon is spotless. This is what he made of himself, and this the memory we will cherish.

To his only surviving daughter, the brightener of his lonely hearth and faithful nurse in his last hours of pain and waning, we extend a sympathy as heartfelt as it is powerless to assuage her grief.

To the poet-brother the assurance that his fame is safe with those who worked with him will suffice. E. D. MEIER.

COMPARISON OF ENGLISH AND AMERICAN TYPES OF FACTORY CONSTRUCTION.

FIRE PROOF FACTORY BUILDINGS.

By John R. Freeman, Member Boston Society of Civil Engineers.

[Remarks Presented September 17, 1890.]

One year ago our President selected mill construction as the topic for discussion at the first autumn meeting and requested that I prepare some contribution, and the remarks and notes which I now present were prepared in response. This evening was fully occupied by interesting speakers. And again at a later date, when the returned European Tourists told their tales, the remorseless hand of the clock got around to the stopping place before my turn came. You must forgive me therefore if the notes have lost a little of their freshness. When these remarks were drafted, a year ago, I had just returned from a tour of some of the principal English manufacturing districts. Some little change has since occurred in prices, but most conditions probably remain unchanged.

The ordinary type of construction adopted today for textile factories in England is radically different from that adopted in the United States. In each country there has been a gradual evolution, and fear of fire has been the most potent force in directing the march of improvement.

EVOLUTION OF THE AMERICAN TYPE OF MILL.

In America this effort to avoid fire has been manifested in an earnest study to make the structure safer without increasing its cost. In America wood was cheap, while iron was dear, and therefore by force of circumstances we were compelled to use wood for pillars, floors and roofs, and the study was to so shape and place this combustible material that it should be under the least favorable conditions for combustion. Such was the progress made that the floors of the earliest mill built in Lawrence (forty-two years ago) were far safer structures than the floors in the latest of the non-fire-proof mills built in England, only a dozen years ago.

For many years this promulgation of the gospel of fire prevention was carried on almost wholly through organizations which have come to be known collectively as the Factory Mutual Insurance Companies of New England, but which, from their original conception and actual organization, could have been named with equal propriety the "New England Manufacturers' Association for Reducing the Loss by Fire." In recounting the good these organizations have done to the cause of fire prevention in mills we should include among them the organization existing for many years among the Lowell mills, and presided over by the engineering skill of our honored member, Mr. Francis.

These associations were under the direct control of boards of direction selected exclusively from the business managers of the mills insured.

Experience shows that a thoroughly destructive fire comes to any particular textile factory—even though poorly protected—scarcely once in a man's lifetime, and the average manufacturer is thereby led to underestimate the value of precautions.

These manufacturers acting in the capacity of insurers were continually receiving object lessons teaching that bad risks were liable to burn, and thus as they built new mills they built with greater care and encouraged their neighbors to do likewise.

Through the effort and encouragement of these "Factory Mutuals" many improved details of construction were introduced or popularized—such as the solid plank floor, the opening up or avoidance of all concealed spaces, and the use of the flat roof—which are now so common and of such self evident value that builders are inclined to think they always existed and never required either inventive skill or persistent urging to introduce them.

Within the past few years the doctrine of fire prevention has been taken up by many able men with renewed energy, and is, moreover, being vigorously preached by various powerful underwriters' associations who have found the agent's unwritten maxim that bad risks give good commissions, to be poor business policy.

The rate of insurance is, in a general way, an index of the hazard, and we are justified in giving these American insurance organizations credit for the good they have done in view of the fact that today it costs the American cotton spinner about the same to insure his mill constructed with posts, beams, and floors of wood that it costs the English spinner to insure the structure and contents of his fire proof mill.

All this effort on the part of the American manufacturer, while using combustible timber, to produce a mill which should be safe against fire, has brought about the discarding of the steep factory roof with its attic and cockloft, the discarding of the joisted floor with its subdivision of timber such that like finely split kindling wood it invites easy ignition and rapid destruction, and the avoiding of all hollows behind sheathing, either on walls or in floor, in which tinder-like flyings could gather, where mouse nests built of greasy waste could be built, or where combustion could smoulder unseen, and has now resulted in the almost universal adoption for the main buildings by our best textile factories, and metal working factories as well, of the general type of construction shown below:

To compare the slow-burning merits of the solid plank and timber floor with those of the joisted floors—we may state that fires in mills have often been extinguished after one inch has been burned off from each side of a 12x16-inch floor beam. This leaves the beam two-thirds as strong as before.

Suppose one inch burned off from each side of a 2×10 floor joist, how much sustaining power have you left?

This standard New England mill construction is so simple, and so obvious are its advantages that most cotton mill men would almost be in-

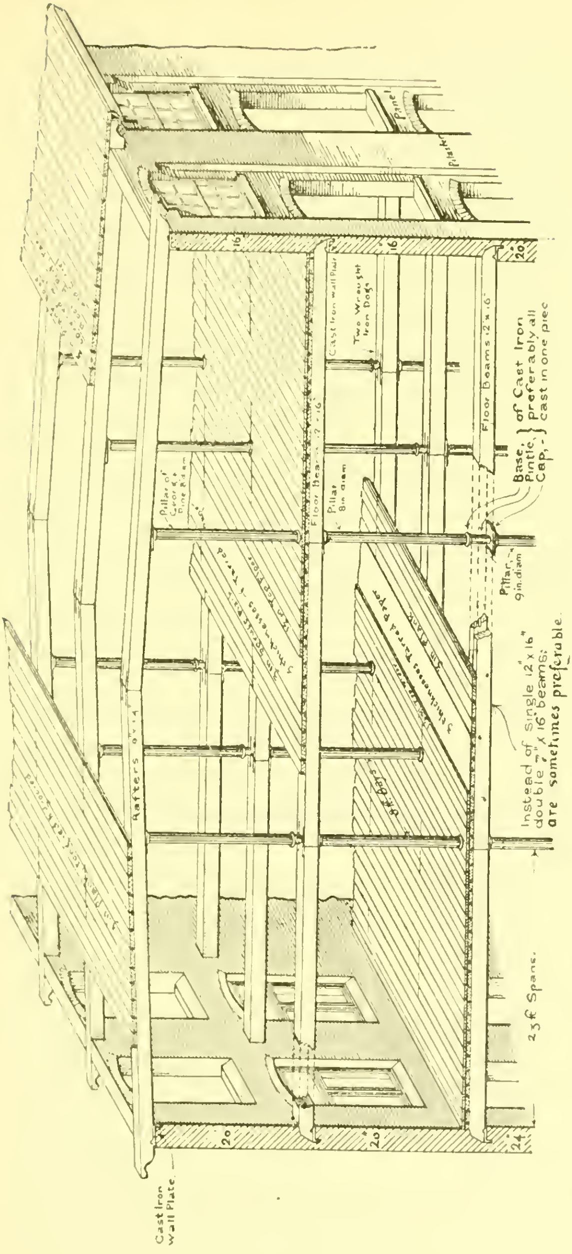
Rafters
Floor Beams 12"x16"
Cast Iron wall Plate
Two Wrought Iron Dogs
Pillar 8 in. diam
Base, Pintle, Cap, } of Cast Iron preferably all cast in one piece
Pillar, 9 in. diam
Instead of Single 12"x16" beams; double 7"x16" beams are sometimes preferable.
3 thicknesses Tarred Paper
8 ft. Bays
25 ft. Spans.
Panel
Pilaster
Cast Iron Wall Plate
16
20
24

FIGURE I.

clined to deny that its origin called for any invention whatever, or that its introduction called for most earnest persuasion to change from the cellular tinder-box floor system of years ago; and to many of you, engineers familiar with the New England factories, it would appear unaccountable that after forty years spent on the journey from Lowell to Philadelphia, this method of construction is only now fairly beginning to get a good foothold there.

Strange it is that outside of cotton and woolen factories the conquest of this type is not yet complete even here in New England. The "Mutuals" are still obliged to send their missionaries to urge the merits of the solid plank flat roof upon the attention of those building paper mills, but here converts are increasing and growing strong in the faith.

It may well seem strange that the ignorance and prejudice of the "Practical Builder," so called to distinguish him from the Mill Engineer, still causes the inferior joisted construction to be the general order of factory and workshop architecture west of the Hudson, and that in New York City and in Boston, though here and there shining exceptions occur, three out of four architects, if called upon to design a factory, workshop or storehouse, would from force of habit, or from the far too prevalent inattention to anything but the ground plan and the picture, still adhere to inferior details of construction, some of which were beginning to be discarded in our best cotton mills almost half a century ago.*

THE ENGLISH TYPE OF MILL.

In England the circumstances about the study of fire prevention have been different. There has until recently been no successful effort of manufacturers to take the question of insurance into their own hands, as was done in New England, and to systematically study the lessening of the fire hazard by inexpensive changes in the details of construction; but as the cost of insurance and the danger of interruption to business by fire accompanying the old style, rather flimsily built structure, has become a serious burden; change in construction far more radical than anything called for here was introduced almost at one broad jump, and while with us the attempt had been only to make the mill "slow burning," the English mill-architect set out to make it absolutely fire-proof. How well he succeeded and what it cost as compared with American practice we will consider further on.†

*Simple as is the type of construction illustrated in Fig 1, defects are often introduced when persons unfamiliar with this class of construction attempt to apply it, and of which a good many examples can be found here in Boston. For instance —1st we find often the use of wooden corbels under the beams and on top of the pillars instead of iron caps, or 2nd, sometimes the omission of the iron pintles—(In either of these methods where pillar bears directly against a wooden cap or beam, the sustaining power of the pillar if of wood is weakened fifty per cent.) 3rd. The introduction of stringer timbers under the beams to transmit the load to the pillars. 4th. Use of too shallow or too small a beam. 5th. Painting the beams before one or two years seasoning. (Kalsomine or "Anti-Kalsomine" may be applied at once, being of a porous nature.

†England is unquestionably the birthplace and main field of growth of this fireproof mill construction, but we have two or three good examples of it among our

There have been more or less of these fire-proof mills constructed in England for a good many years, but the general adoption of this type is recent. They are now in England the order of the day.

For ten years past throughout the length and breadth of Lancashire there has hardly been a single cotton or wool spinning factory constructed which is not of the "fire-proof" type, and for many of the best modern machine shops the same kind of construction is adopted. In these "fire-proof" mills all floors are composed of brick arches or concrete masonry carried by iron floor beams and supported by cast iron pillars. The inner face of the walls and the top of the rooms are surfaces of bare masonry, and the only woodwork to be found any where in some of these structures is the window sash, although commonly, but not always, there is a little other wood to the extent of a thin top floor of boards laid directly on the masonry floor as being more comfortable for the feet of the operatives.

As I have already said, this type of mill is not new. In Fairbairn's celebrated book on the "Application of Cast and Wrought Iron to Building Purposes," published about thirty years ago, a better general description of this kind of structure is to be found than I have seen in any more recent book. From this treatise we learn that the first successful application was at a seven story mill 140×42 feet, erected in 1801. This had 9-foot bays and 14-foot beams, and its iron work was designed by the famous Engineers Boulton and Watt. The beams were 13½ inches deep of an inverted T shape, and between these beams shallow brick arches 4½ inches thick at the crown, 9½ inches thick at the haunches were turned which after being levelled off on top formed the floors of the mill.

For a quarter of a century this mill served as a model for those cases where fire-proof construction was desired. As early as 1827, Fairbairn, who had a number of fire-proof buildings on hand was led to entertain some doubt as to the security of the cast iron beams, and so started Mr. Hodgkinson on his celebrated experiments upon cast iron girders. As a result of Hodgkinson's experiments the confidence of engineers was increased, the span for cast iron girders was lengthened, and Fairbairn even built mills with cast iron girders of 26 feet span.

Even as in New England we had the sad accident of the fall of the Pemberton, so in the older country they were not without their accidents. At Oldham, in 1844, a cast iron beam broke in a cotton factory, and upward of twenty persons were buried in the ruins. Two other serious acci-

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New England factories, namely, the printing room of the Manchester Print Works, at Manchester, N. H.; the machine shop of Brown & Sharpe, at Providence, built seventeen years ago; and the main building of Colts' Armory, at Hartford, built a little more than twenty years ago to take the place of a building destroyed by fire; and if we turn from factories to the vast office buildings of some of our American cities, and in which Chicago stands preeminent, or to hotel structures like Powers' Hotel or the Palmer House, we shall find examples of this type of fire-proof construction, which for perfection of detail cannot be equalled elsewhere in the world.

Scientific computations and rules of practice for the construction of fire-proof floors are gratuitously published in the small advertising hand-books of some of our American rolling mills, which give much more convenient practical information on these subjects than can be found in any book whatever, published on the other side of the Atlantic.

dents of a similar nature are recorded as occurring in adjacent parts of Lancashire prior to 1845. These accidents led to other experiments and to greater care, and manufacturers went on occasionally building these fire-proof mills, but as said elsewhere, the general or, indeed, almost universal adoption of this type in England is of recent date.

If we go back fifty years, or even thirty years, and look at the type of mill floor then common in England, we find it to have been generally built as shown in the sketch below, Fig. 3, which I made from an old mill in Manchester still in use.

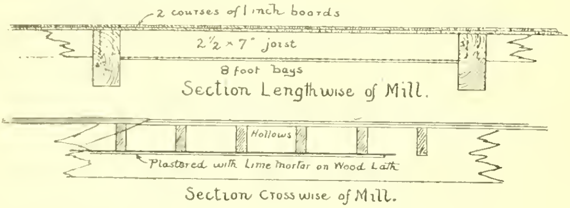


FIG. 3.—SKETCH OF OLD HOLLOW MILL FLOOR.

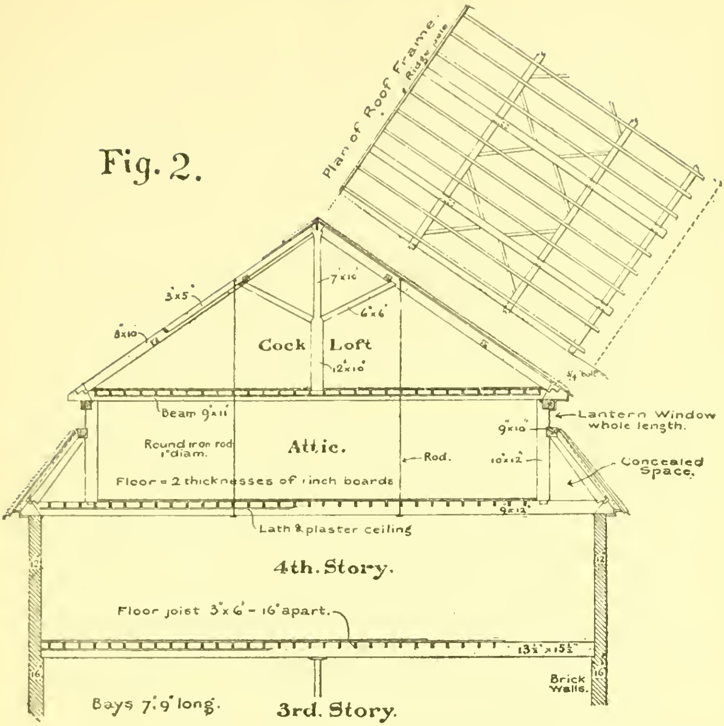
The ordinary cotton mill of New England of the same period was built in a very similar manner, and in both countries the experience with these thin, hollow floors proved them but flimsy barriers for resisting the spread of flames from one story to another of the mill. The plastering quickly fell off from the wooden laths when a fire occurred below it, and time and time again in England as in America, was proved the danger that lurked in these hollow or concealed spaces between the floor joists. The hollows become, after a time, filled with lint to an extent which one unfamiliar with repairs on such structures can hardly believe. This lint was always as ready as tinder to nurse a spark, by the drippings of oil and water through the floor cracks this lint might be brought into condition for spontaneous ignition; and a spark of fire once present in these cavities was shielded from extinction.

The danger of this style of floor was finally clearly established both in England and America. In England the remedy proposed was a floor of incombustible material; while, as already mentioned, in New England the remedy adopted was far cheaper, but has proved almost equally effective, one of avoiding cavities and placing the timber in its least inflammable shape—as shown in Fig. 1.

The fire-proof construction adopted in England—though first introduced so very many years ago—did not become by any means universal. Its higher cost was against it, and thus down to about a dozen or twenty years ago, as I am told, a majority of the floors were built of the form shown in Fig. 4, which I sketched recently from one of the best of the non-fire-proof mills about Manchester.

It will be seen that this floor is similar to many still used in America outside the textile mills, but is thinner and much less substantial than the standard American mill floor, and although the concealed spaces of Fig. 2 are avoided, yet the use of joists gives more corners for fire to attack, and

Fig. 2.



SKETCH OF AN OLD NEW ENGLAND FACTORY ROOF AND FLOOR.

presents more surface to flames, besides being unsightly. The thinner floor-plank gives a less stable hold for screwing down the machinery.

Higher cost of lumber is not a valid reason for the adoption of this floor

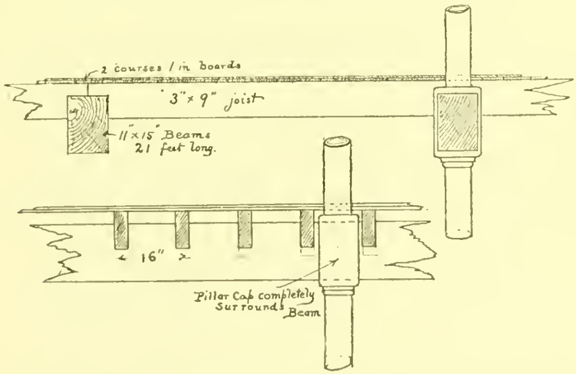


FIG. 4.—SKETCH OF MORE RECENT ENGLISH WOODEN MILL-FLOOR.

in either country; for a very little figuring will show that 3×9 joist placed 16 inches apart contain the same amount of lumber as would a thickness of 1.81 inches evenly distributed over floor; this added to the 2 inches of boards gives 3.81 inches or just the same as for a floor of 2¾ inch plank with a 1 inch board on top.

The mill from which this sketch was made was built only about sixteen years ago, and was among the latest of the non-fire-proof mills built in the Manchester district. This joisted type of floor became obsolete, or no longer constructed among our better American mills, about forty years ago, and this mill is but one illustration of the general fact that this inferior type of floor continued to be built in England long after the best cotton mill builders had discarded it in America, and that there was in England a sudden transition from the objectionable joisted floor to the fire-proof floor without the solid plank floor of the American type having had a fair chance to demonstrate its merits.

As to the relative proportion of fire-proof and non-fire-proof textile mills now running in England, the chief surveyor of one of the principal insurance companies gave as his judgment that forty per cent of all the mills are of the fire-proof type; but as stated above, the textile factories built in England during the past ten years have, almost without exception, been built with fire-proof floors.

There are several different systems in use for constructing these floors, each of which has its advocates; but before illustrating more of the floor systems we had perhaps best illustrate the typical form of a complete English spinning mill of today.

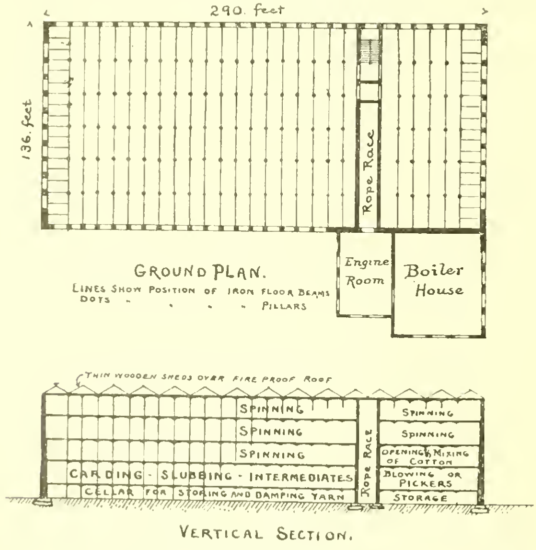


FIG. 5.—OUTLINES OF MODERN ENGLISH COTTON MILL.

Of course there as here the lay of the ground or the caprice of the owner may vary the shape and general arrangement of the mill, but after having visited quite a large number of the newer mills I think we may with little question present the sketch above as apparently the ordinary and favorite type today for mills spinning white cotton yarns.*

It will be noted that its width is much greater than customary in America, where 100 feet is now the general accepted maximum. This width of six sections between pillars, about 21 feet apart, thus giving a mill of from 132 to 136 feet outside measurement, is now nearly always adopted; and is more readily admissible from the fact that these are simply spinning mills and the requirments for lighting thus more simple.

It is to be remembered that the illustration shown is for a mill of the largest size, or about 90,000 spindles. Until within the past four or five years mills of only half or two-thirds this capacity have been the more common, and in these smaller mills the width is the same, the difference in floor area being made up wholly by change in length of the mill. Such mills are about as broad as they are long, and thus strike the American as very oddly shaped.

The reason for this great width is that the spinning mules are almost invariably placed crosswise of the mill, and that this distance accommodates the number of spindles which experience has shown can be operated with greatest economy. A less width of mill will not accommodate the full number of spindles which it is possible for one man and his helper to operate. It is said that the carriages have reached the utmost limit of length found consistent with rigidity, and that there is thus no gain in building wider.

The average daylight in England is much less brilliant than with us, and yet they build their ordinary modern mill thirty feet wider than we do. This superiority of the English type of window has been recognized by a few of our manufacturers for several years.

In New England the earlier mills were between forty and fifty feet wide; and not many years ago, by reason of the difficulty of lighting a wide space, seventy-two feet was considered in this country to be the maximum width advantageous for a cotton mill of several stories. In our more recent mills greater study has been devoted to obtaining a larger proportion of window area, and a foot or two has been added to the height of each story; and 100 feet in width has now come to be that generally accepted as the most advantageous for an isolated building.

In one or two instances in the past where greater widths than this for mills of more than one story have been attempted in New England, the results have not been satisfactory, by reason of defective illumination in

*One point in the layout of these English spinning mills that is very worthy of note is the strong effort everywhere apparent in the later mills to provide room enough for all the carding and roving machinery on a single floor. Very often the area of the first story floor is largely extended with this in view, by one story annexes in full communication with the main room, the main mill wall over this juncture of the annex with the mill being carried by heavy pillars and girders in this story. The object attained is greater economy of operation and supervision.

center of room. It must be kept in mind, however, that the American mill usually has weave rooms in its lower stories, thus making the conditions more exacting.

In one or two of the new mills just built in Fall River, by carrying the clear height of the story up to between fifteen and sixteen feet and using a window more nearly approaching the English form, a width of 120 feet has been adopted with success. A few mills have been built in Massachusetts during the past half-dozen years with windows substantially of the English type,* and among these are some of the very best lighted mills that can anywhere be found. The new Washington mills, at Lawrence, Mass., with the two main buildings each 100 feet wide by 400 feet long by five stories high, designed by Stephen Greene, may be mentioned as one good example where the wall and window are substantially of the English form.

This form has as yet by no means come into general use in New England, and it does appear that up to the present time the matter has received far less attention than it merits. For it is this greater thickness of wall and greater area of window which have made it possible for the ordinary modern English cotton mill to be built thirty-three per cent wider than the ordinary modern American mill with the same clear height of story. It is thus the form of the window and wall to which we would direct attention rather than to the width of the mill.

THE "ENGLISH MILL WINDOW."

Of course the windows of all English mills are not alike in their details, but we may select the one shown in Fig. 6—which I sketched from a thoroughly first-class mill now under construction—as illustrating the general features.

It will be noted that the outside wall of the mill is in one sense hardly so much like a wall, as it is to merely a row of brick piers three feet square and ten and one-half feet apart, with the space between them filled mostly by glazing. The glass goes up to within a couple of inches of the ceiling. In some cases the panel under the window (at *A*) is only a foot thick. (This seems to be a judicious saving of brick and gain of alley-way, especially in view of the piers being tied together by such a very rigid floor system.) But generally the part *B* is made of the full thickness of the pier.

The top sash *C* pivots on a horizontal axis, and thus is readily opened

*While on this subject of so arranging windows and walls as to obtain the maximum of light, interest attaches to some mills recently built in New England from the designs of Mr. Moses Oliver, of Lawrence, who also is one candidate for the honor of having originated the flat, thick plank and timber factory roof. Mr. Oliver went even further in thickening the wall or pier between the windows than shown in Fig. 6, and correspondingly increased the window area, and at the same time stiffened the wall. In some of his examples there was the unattractive feature of a broken batter to the outer face of the piers, but this could readily be avoided and still retain the relatively large window area and stiff wall. Perhaps one of Mr. Olivers' best efforts in this line is the printing building of the Cocheco Print Works at Dover, N. H. For high buildings, the pier becomes so deep as to cut off much of the diagonal light; and this diagonal light is a feature which by no means should be lost sight of while designing.

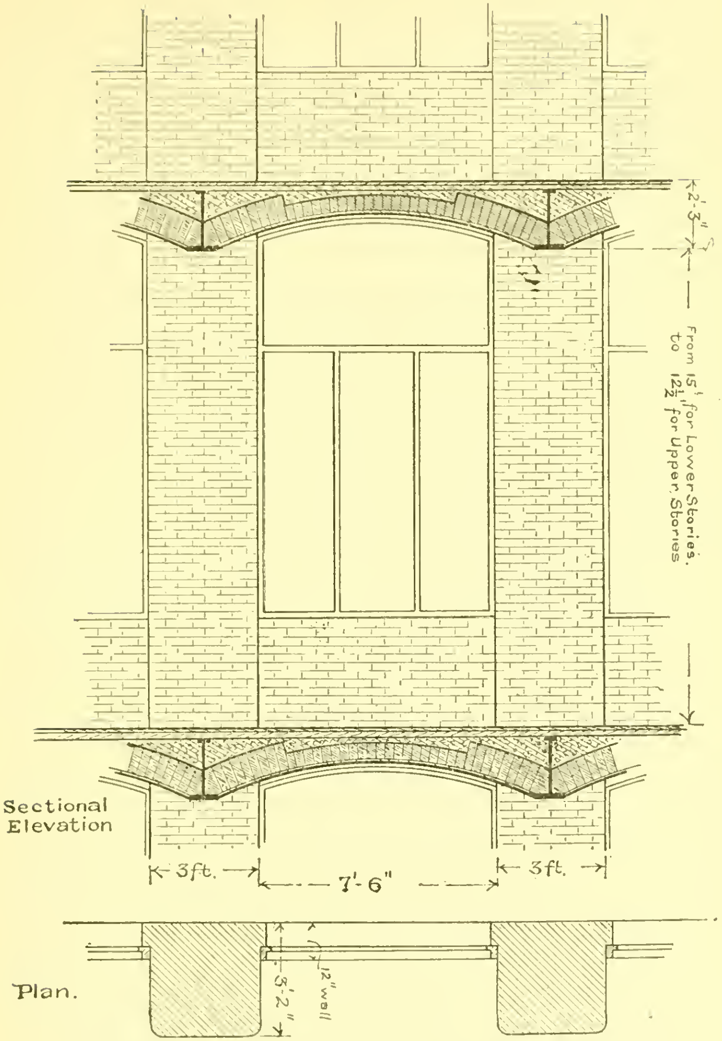


Fig. 6.—The English Mill Window.

and adjusted for ventilation, while the lower sashes are stationary, that is they do not slide up and down. (Once in a while one of them is hinged like a door.)

A very noteworthy advantage is thus had by doing away with sash weight boxes, and so gaining several inches in width of glass and at the same time reducing the obstruction by the mullions or central vertical post.

Round cornered brick are used almost invariably for forming the corners

about the inside of the window opening, and are often used at outside of window also. Our American mill builders are making use of these round cornered brick more and more; but still they are not used in more than one new mill in a dozen, which is almost unaccountable considering the very neat finish, together with the slight increase of diagonal light, which they give at no additional expense.

For the glazing, unpolished, rolled plate glass about ¼ inch thick is very often, but not always, used in England, and has also been adopted in two or three recent American mills. This semi-transparent glass gives a soft diffused light even on the sunny side, and makes curtains unnecessary, and being more than twice as thick as our ordinary window glass, keeps the room a little warmer. Some times this rolled glass is used only for the lower

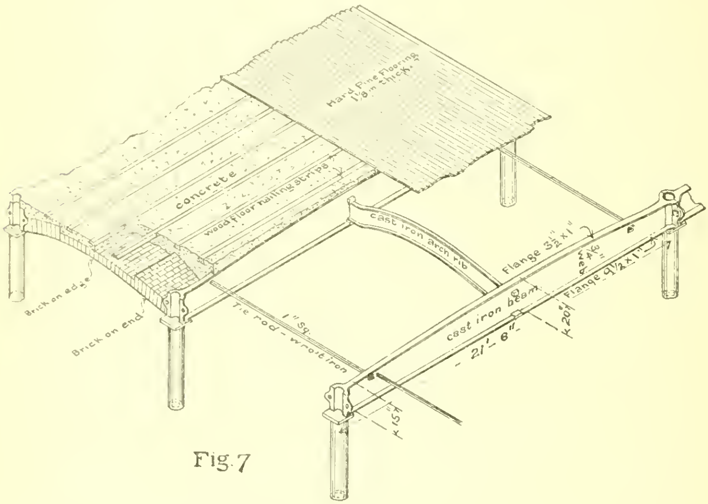


Fig. 7

half of window with thin, clear glass above. Its purpose then appears to save breakage and keep the operatives from staring out of the window. To me it gives a prison-like aspect to the room.

In Fig. 8 a somewhat neater form of pier between windows is indicated and the flaring window jamb would tend to compensate for the slightly diminished width of glass, and this sketch may further remind us that by thus forming the pier we save a greater part of the diagonal light.

In Fig. 8 a different form of sash is also shown. In this, ventilation is secured through a part of sash hinged at its bottom and known as the "Hopper Ventilator."

Now to return to the subject of fire-proof mills, the only structural difference between a "non-fire-proof" and a "fire-proof" mill, so called—is found in the floors and in the roof. The type of fire-proof floor, of which more have been constructed than any other, and which in its general arrangement is the type followed for many years, is shown in Fig. 7.

This was sketched from a four-story mill, now under construction; and intended to be a thoroughly first-class mill in every respect; and this example thus serves to illustrate that the old 10-foot arch on cast-iron beams still survives in good practice. In this particular mill the manager told me he preferred cast-iron to rolled iron beams, believing that they gave a more rigid floor. We may mention as a novel feature and as illustrating the general excellence aimed at in this mill, that throughout all stories of this mill enamelled brick were used for facing inside of walls up to a level of about 4.3 feet above floor. This gave a non absorbent surface easily kept neat.* Above this the walls were to be whitewashed.

The pillars are of cast-iron and are hollow. A broad collar is cast upon the upper end of the pillar, and on this collar rest the ends of the two floor beams. The ends of these cast-iron floor beams are formed so as to encircle and firmly grasp the upper end of the pillar, and above the girders the cylindrical end of the pillar projects two or three inches, and upon it rests the cup-shaped base of the pillar of the story next above. The bearing surfaces of these two ends of pillars are trued up in a lathe, but in some examples which I saw the bearing of the girder on the pillar was left as cast.

Fig 8 is reduced from tracings furnished me with great kindness and in a most liberal spirit by Messrs. Wild, Collins & Wild, mill architects of Oldham, England. The mill was just nearing completion at the time of my visit and is a fine example of a first-class modern English mill. The window details are somewhat different from those shown in Fig. 6.

The outside walls of the mill were carried to their full height, and the pillars, main girders and the tie-rods between them put in place throughout all stories—thus forming a vast shell and skeleton—before the laying of the arched floor itself was begun.

In many structures the cast-iron arched stiffening rib at center of girder (A—Fig. 7) is omitted and its place taken by an ordinary tie-rod.

Without at present computing the strength of these tie-rods relatively to the whole thrust of a full load on this flat arch, attention may be called to a feature, sometimes omitted from our American structures with arched floors, but which appears to be always present in these fire-proof mills. The series of transverse arches is not carried out clear to the end so their haunches thrust directly against the end wall of the mill, but at the end of mill a strip of floor 10 or 20 feet wide is built with beams running perpendicular to the wall or in the other direction from most of the arches. Exactly how much this helps the stability is hard to say, but evidently it is of value.

Another feature which will probably strike the attention of the American engineer on going through some of the English fire-proof mills is that the pillars look small in proportion to the great weight of the floor structure, in comparison to those used in America. I did not give particular attention to this matter,

*Referring to the free use of enamelled brick, I saw under construction at the Fairfield Shipbuilding Co.'s, on the Clyde, a boiler shop situated between other buildings, and lighted from the top, in which the whole inside was faced with white enamelled br

but assumed that at the very home of Fairbairn and Hodgkinson these pillars would be the subject of scientific design. At one new and most excellent mill where I did obtain the dimensions, I found the actual load in the lower stories two and a half times as great for a pillar of given size, as our best practice would give. Very likely the explanation of the apparent small size may be that instead of following the course outlined in the prudent tables of Mr. James B. Francis on the strength of cast-iron pillars, and ordinarily computing their strength as having rounded ends, as is common in American mill engineering,—great prudence having been taught by the fall of the Pemberton mill,—they consider that this very rigid floor system makes it proper to assume the pillar as having "*square*" or fixed ends." Granting this assumption as justifiable, it follows, of course, that for a given size of pillar three times the load may be allowed.

I had expected that in this land of iron foundries pillars would be of the very best class. I was informed by a leading mill architect that notwithstanding the well known superiority of pillars cast on end over those cast on the side, nearly all mill pillars are still unfortunately, in England as in America, cast on the side; this method being somewhat cheaper and available by the ordinary local foundries.

It might at first thought appear that this solid masonry and iron ceiling would be inconvenient for attaching shafting hangers and the numerous pipes and fixtures necessary, but such is not the case. All such fixtures are attached very easily and cheaply at any time, by means of bolts with claws catching on over the edges of bottom flange of the iron beam.

In the English fire-proofed mill stairways and elevator shafts are separated from the rooms by brick walls and there is rarely a belt hole through the floor. Unfortunately for the fire hazard, it is the almost universal practice in American mills to belt machinery in certain rooms through the floor. The desire for belt holes through the floor is the great obstacle to inserting a $\frac{3}{4}$-inch layer of mortar between the top course and the plank of our American floors.

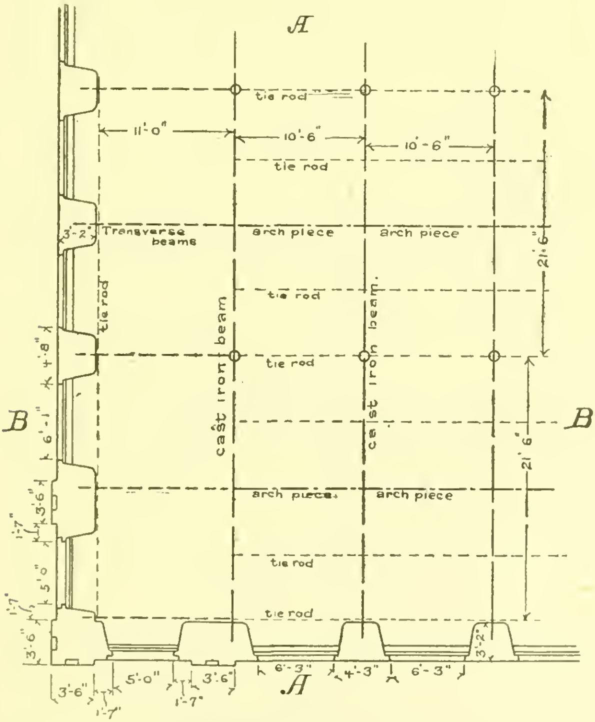
The standard brick common in England are much larger than our American brick, so that a thousand make double the number of cubic feet of wall. The standard bricks are $9 \times 4\frac{1}{2} \times 3$ inches, and this gives a heavier arch, but in this particular mill a special and even larger brick was used for the arches, giving a thickness of 6 inches at crown. Except the skewback, which is a brick of special shape, ordinary flat brick are used in the arches. These are laid in mortar with joints of full ordinary thickness instead of being packed dry over a water-tight center and then

*Some of the practical handbooks published by American rolling mills imply that this prac[illegible]ce of computing the strength of fire-proof floor pillars as for "square ends" is proper, and do not so carefully limit this application as did Mr. Francis. The Francis tables are much the more prudent guide. In some cases the assumption is that the bearing is symmetrically distributed over a true and rigid surface of the full size of the pillar proper, but in considering how far such a supposition is admissible we must bear in mind that this fixing of the end becomes an element of weakness instead of strength, so soon as the application of the load becomes unsymmetrical.

grouted with cement as we consider preferable in similar cases on this side of the water.

The movable wooden centers for the arching are hung from the lower flanges of the girders and are struck and slid ahead soon after the work is closed up behind them, and a few pieces of centering thus serve for the whole mill.

The concrete filling is made up mostly from broken bricks. The floor surface is in some mills throughout all stories formed of flag stones bedded in this concrete, but more often flag stones if used at all are used only upon the first floor, and in nearly all of the newer mills the floor surface is formed of one thickness of 1¼-inch boards nailed to 3×4 joist 2 feet apart, imbedded in the concrete as shown in the figure 7. A steam mortar mixer, which served for the brick work and the concrete work, formed regularly a part of the builder's outfit in each of the mills under construction which I visited.

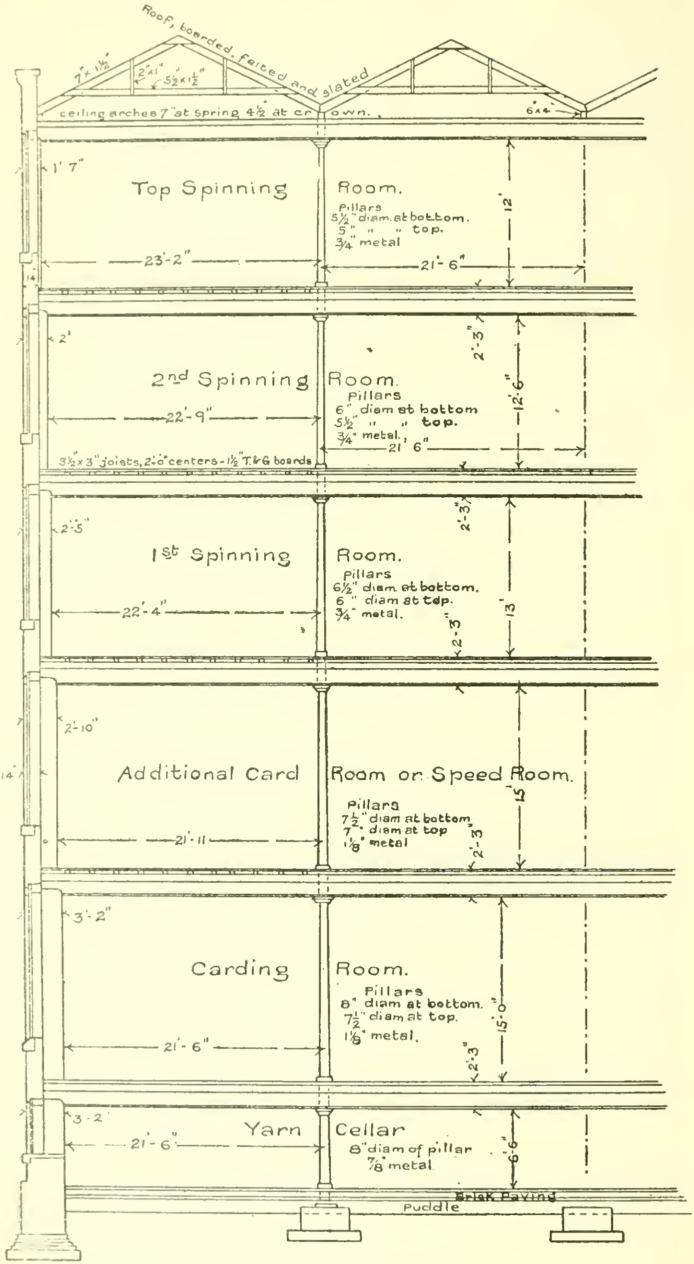


Ground Plan.

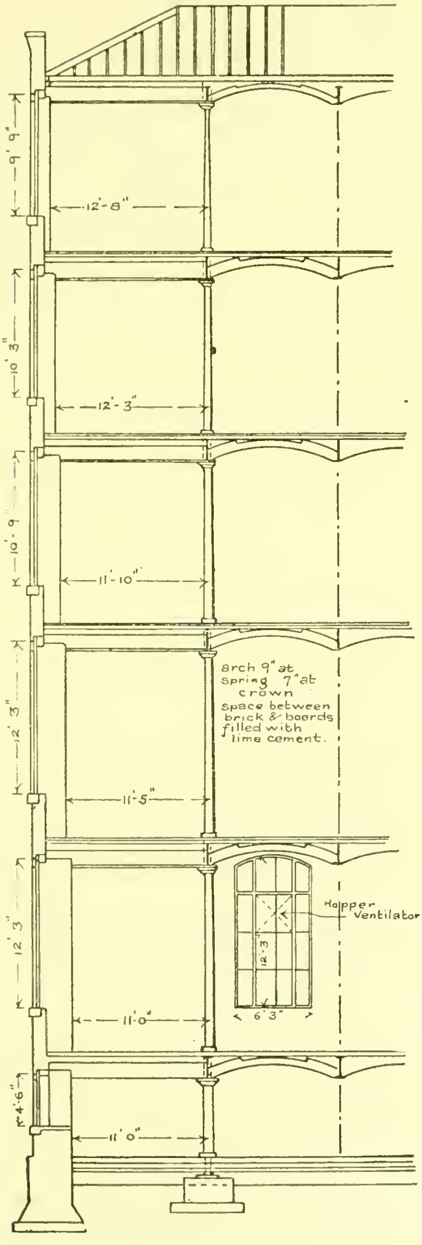
FIGURE 8.

LION SPINNING CO'S MILL, OLDHAM. Erected 1889.

Messrs. Wild, Collins & Wild, Architects.



SECTION A. A.—FIG. 8.



SECTION B. B. FIG. 8.

The under side of the brick arch in all these structures shown in Figs. 6 to 10 is smoothly plastered with a coat of ordinary mortar about ¾ inch thick. This adheres readily to the rough surface of the brickwork and sticks so securely that in the mill referred to below as thoroughly wet down during a fire and soaked from top to bottom, not a particle of this plastering flaked off. This surface is kept well whitewashed and the whole forms a very neat ceiling, making the general appearance of the room much brighter and pleasanter than one might expect, and without any oppressive suggestion from the great weight of the ceiling. No special effort to make the floors waterproof appears, although this would seem easy thing to do; and when fire occurs in an upper story the water percolates freely and the whole mill gets wet down. The floor is in fact much less waterproof than the ordinary American floor, as I had opportunity to observe at one mill of this construction where a bad fire had occurred a few days prior to my visit. Water is said to percolate much less freely through the concrete floors shown in Fig. 12 than through the brick arches.

The older fire-proof mills were built with cast-iron beams, to-day these are still adopted in some cases, and sometimes the first floor is made with cast beams and rolled beams used for all floors above; but for a dozen years past wrought iron beams have been the most commonly used throughout all stories. It may be of interest to note that nothwithstanding the great number of steel and iron works near at hand, the English mills procure these rolled beams almost wholly from Belgium where cheaper labor gives a lower price.

With these later structures with the rolled beams it is also usually the case that brick of common size and shape are used for all of the arch, except the skewbacks; and excepting for the substitution of rolled beams, and the use of a tie-rod instead of an arched brace at *A* there is no essential difference from the construction shown in Fig. 7.

Fig. 9 represents a style of fire-proof floor construction of which many examples are to be found, which has originated in the effort to avoid such heavy brick arches. The structure of the main wrought iron beams and the pillars, is arranged precisely as in the preceding figures, but a second

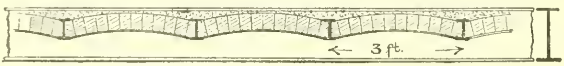


Fig. 9.

system of small wrought iron girders are added, and bolted to the main girder, which thus serves to carry their weight and to take up the thrust from the arch.

The arch is of a single course of brick; this is levelled up with concrete and covered with a thickness of boards as before. The smaller span of the arch and less depth at the haunches gives a floor which may be of considerable less weight than Fig. 6 or 7.

I also saw examples of the same style of floor system with the beams of cast-iron instead of wrought iron, and in these the ends of the joist or

smaller beam rested in lugs cast for this purpose projecting from the web of the main beam.

Fig. 10 illustrates still another method of obtaining shorter spans for the brick arch, and at the same time getting a ceiling more favorable for good illumination of the room. This formed the subject of a patent (now expired), by J. H. Stott & Sons, a leading firm of mill architects of Old-

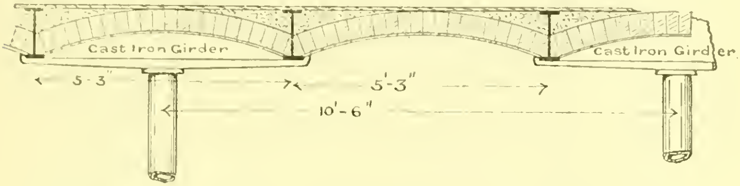


FIGURE 10.

ham and Manchester, and several large mills were constructed by them on this principle. I had the pleasure of visiting one of these, the Astley Mill of Dukinfield and found its rooms light and airy and the whole effect of the structure pleasing.

The same firm of architects have recently introduced another innovation for a cotton mill floor system* by which the mill is built with only half the number of pillars heretofore customary; in other words the distance between pillars is 21 feet, instead of 10½ feet. This economizes room and gives more convenient access between the mules. The arrangement as kindly explained to me by Mr. Stott, consists in running stringers 21 feet long consisting of a pair of beams *A B*, from pillar to pillar in one direction and upon these beams supporting the ends of the transverse beams from which the brick arch is sprung, as shown in the sketch.

Messrs. Stott & Sons had already erected two or three large spinning mills on this principle and had another under construction at Stockport.

CONCRETE FLOORS.

This form of fire-proof floor has come into use within a comparatively recent period.

I saw good examples of it in three different towns, but understand it is even at the present time not adopted so often as the brick arch. It has the advantage of a flat ceiling and makes the appearance of the room neater. At one first-class and well known mill, I was told they adopted it

*The new fire-proof machine shop of the Brown & Sharpe Mfg. Co., of Providence, R. I., built in 1887, has its floor systems and pillars similarly arranged, and for their purpose certainly gives a most excellent unobstructed room.

In the new weave shed of the Otis Co. at Ware, Mass., designed by our well known Providence mill Engineer, Mr. Sheldon, it has similarly been found advantageous to do away with half the ordinary number of pillars. Our standard New England plank and timber mill construction (Fig. 1) lends itself readily to a similar modification of the arrangement of beams and pillars and for upper stories or low buildings—and for floor loads of 30 lbs. (exclusive of floor itself), or like those common in most textile works, this reduction of the number of pillars may often prove well worth seeking.

because they found it cheaper than brick arching. On another occasion a mill architect assured me that if properly done, it was considerably dearer than brick arching. And finally at one of the finest and best known works in the kingdom, an establishment where pride is taken in maintaining a reputation for doing everything in the most thorough manner, I found that a new mill now under construction, was being built with concrete floors.* Thus the relative merit of this type of structure appears still to some extent an open question, but certainly some of the best mill architects prefer the concrete as being both better and less costly. They make its small ribs of steel joist—and state that a first-class concrete floor can be built for about 8% less cost than the brick floor.

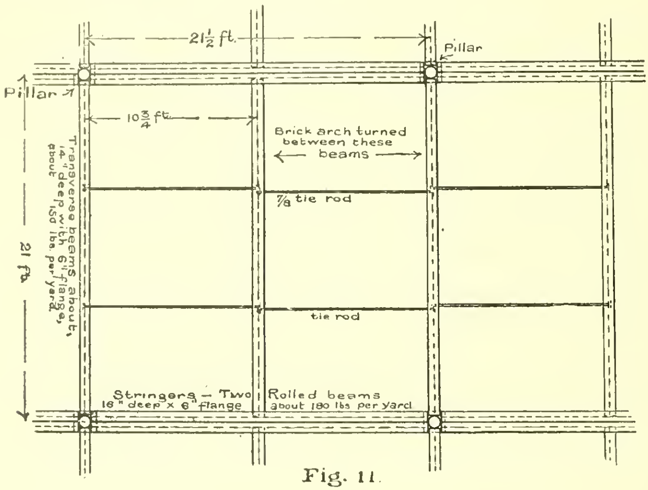


Fig. 11.

Some underwriters are regarding this type with a little apprehension, lest the fact of the main girder being wholly exposed may lead to serious injury to the structure in case of fire. As yet they have happened to have no serious fire in this type of structure from which it could be learned, practically whether this fear is well grounded, and thus no difference in the insurance rate is recognized between this and the brick arch.

The architects of this mill of the Messrs. Coats, Messrs. Morley and Woodhouse, Bradford, Yorkshire, write me: "The advantages of the concrete are: It is more compact, and more quickly done. The combination of the iron members is more perfect. The steel girders are much lighter than cast-iron and much more reliable. With the concrete floor there is an absence of thrust on the walls."

In this mill of the Messrs. Coats the iron work is wholly covered and shielded from possible flames. The pillars are plastered three coats on galvanized wire netting and the beams are also encased in netting and plastered three coats. This netting and plastering does not follow the

*J. P. Coats' thread works at Paisley, Scotland.

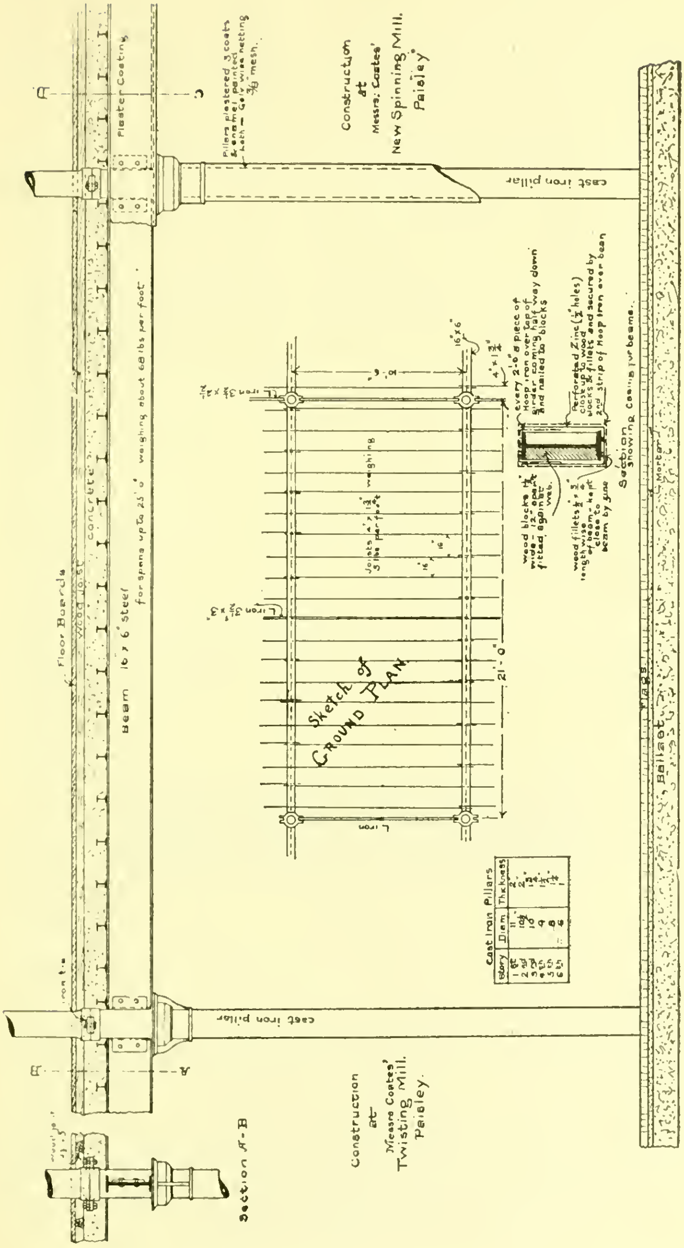

Floor Boards
Concrete
Plaster Coating
Beam 16 x 6 steel
for spans up to 25' 0" weighing about 68 lbs per foot
Construction at Messrs. Coates' New Spinning Mill. Paisley
cast iron pillar
Sketch of Ground Plan
21' 0"
Section showing Casing for beams.
Flags
Ballast
Mortar
Cast Iron Pillars
Story
Diam
Thickness
Construction at Messrs Coates' Twisting Mill. Paisley.
Section A-B

FIGURE 12.

contour of the sides of the beam but runs straight vertically between the edges of flanges, this leaving a hollow or air space each side of the center. The concrete consists of 5 parts of broken brick, broken stone or furnace slag, to one part of Portland cement. The wood flooring strips are bedded in mortar on the concrete and then (optionally) filled between with a cheap mortar or concrete made of ashes and cement in the proportion of 9 to 1.

Fig. 12 is reproduced from tracings very kindly furnished me by the Messrs. Coats—and the two styles of pillar represent different details of pillars followed in two of their most recent mills; that at the right differing from the other in that the exposed iron work is protected by plastering on wire lath.

I may mention as showing the difference in the practice of different builders that at another recent mill I found the floors supported on a similar arrangement of beams, with the smaller cross beams perhaps closer, but with the concrete only a little over 6 inches thick, or about half as thick as in this mill shown in Fig. 11.

I visited in all some 15 or 20 representative factories and believe the foregoing examples to illustrate fairly well the styles of floor in general use.

In every case the pillars were cast-iron and unprotected by any covering. In each case of concrete mill the main girders of wrought iron were fully exposed. In every brick arched mill the bottom flanges of all the girders were without any covering.*

The construction of hollow terra cotta floors such as shown in Fig. 13, by which the enormous dead weight of the masonry is greatly reduced, and the weight and cost of the iron work thereby lessened and above all in which the iron work is protected from the direct contact of the fire, which

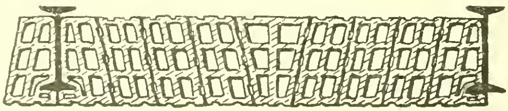


Fig. 13.

have been quite common for important buildings in the business centers of Boston, New York and Chicago for some years past appear to have been almost unknown in England until recently introduced by Messrs. Doulton & Co.*

The free use of the inexpensive forms of hollow flooring tile now so common in Chicago, New York and Boston, and the careful protection of

*Hollow brick were used in the floors of the noted mill of Titus Salt, at Saltaire, Yorkshire, many years ago, but the iron was exposed as usual.

iron girders and pillars from direct contact with the flames are points apparently well meriting more consideration from the English mill architect.*

ROOFS.

In past years a good many mills have been built with the floors fire-proof but the roofs non-fire-proof.

I found roofs to-day covering some of these English fire-proof mills, to be examples of the worst kind of combustible architecture. They were built wholly of wood, with joisted framing, concealed spaces and hollow sheathing, and were not flat but were slated and sloped at about 30° in a succession of peaks and valleys. For safety they are not to be compared to the equally cheap timber roof shown in Fig. 1, introduced about 30 years ago and now universally adopted at the best American mills.

It so happened that a roof of this pitched hollow wooden class was burned off from a large mill just as I arrived in Lancashire and I thus had an opportunity to study the remains. The fire took in a mule carriage in the middle of the forenoon. Smoke drove men from the room, fire got into the roof, hydrant streams failed to extinguish it until the greater part was consumed; the fire-proof floor and the water which flooded it held the fire from going lower, but the whole mill was thoroughly wet down. I was interested to note that although this fire was a very hot one so that before it could be extinguished 12-inch wooden beams across tops of pillars were reduced to about one-half of their original thickness and 2-inch shafting was softened so that it bent freely; that although two columns out of the sixty or seventy contained in the room were crooked a few inches by the heat, yet all of the others were apparently uninjured.† It is to be kept in mind however, that the load upon these pillars was very light indeed, and that pillars in a lower story might have fared differently.

For many years some mills have been built with the fire-proof construction extended to the roof. At present nearly all are built with fire-proof roof.

The main part of the roof is constructed in all respects like a floor ex-

*The fire-proof floor now being introduced in Boston and New York by the Gustavino Construction Co., ought not to pass without mention when fire-proof construction is discussed. The comparative freedom from iron and consequent freedom from liability to be torn by its expansion—the novel cohesion of the arch and the utilizing of the tenacity of the cement are all points which may well arouse the interest of the architect and engineer.

†There is a good deal of loose talk prevalent about the unreliability of cast-iron as a structural material. The writer would of course not for an instant deny the superiority of wrought iron or rolled girders to resist a sudden blow, but would merely oppose the notion that cast-iron pillars are so quickly made brittle or "rotten" when touched by the flames or that they crack like glass when in a room on fire they are touched by a hose stream. The cast-iron pillar is many times a most useful member and sometimes the best possible thing that the circumstances will admit and ought not to have its character thus defamed. The writer has carefully examined the ruins after several severe fires to see how the iron pillars fared. In the Boston Thanksgiving day fire of 188[illegible], though a considerable number of the pillars in the Ames building were broken apparently by their own fall or the fall of debris upon them, very few comparatively, bore evidence of yielding to the heat, and the same was generally true of the pillars in the wreck of the great Lynn fire. The case of the English mill mentioned a little later on may also be referred to.

cept that the top boarding with its small joists imbeded in the concrete is omitted. On top of the coarse concrete used in levelling up between the arches, a thin layer of finer concrete of cement mortar is placed.

Then in one method of construction, which has for some years and until recently been the favorite, two layers of melted asphalt are spread over the top surface and, the mill walls having been carried up all around some two feet above the general level, after the asphalt is set water is pumped up on top of the roof to a depth of 6 inches or a foot. This pool stands on the roof summer and winter; in winter it freezes and might be utilized as a skating rink only that the low parapet makes the prospect of a fall rather startling. The object of this pond upon the roof appears two-fold. First it may serve as a ready supply in case of fire, second, it is said to preserve the asphalt covering.

In the mills with fire proof roofs most recently built this method of having water permanently on the roof is no longer followed, but on top of a masonry roof, a series of small parallel pitch roofs consisting of light wooden shells covered with roofing slate are used, as shown in the longitudinal section of Fig. 8, the hollows under them are unused and inaccessible.

TO WHAT EXTENT ARE THOSE SO-CALLED FIRE-PROOF STRUCTURES FIRE-PROOF?

As to whether a building is fire-proof or not it is merely a question of the intensity of the fire. The iron bound fire-brick arch forming the roof of an open hearth steel furnace may resist the most intense heat known to practical science for weeks, and even the common red brick work of a mill would probably endure for a considerable time a heat approaching dull redness. Instances were rare where the fiercest heat of the great Boston fire of '72 softened the brick themselves. The calcining of the mortar would probably be the first weakness developed.

The weakness of the brick-arched structure lies in its iron.

We are told that certain so called "fire-proof" structures in the great fires of Chicago* and Boston resisted hardly a moment longer by reason of the incombustibility of the material of which they were constructed. It is said that the expansion of iron work cracked and ruptured the masonry. Rolled beams were softened or cast-iron pillars weakened by heat generated by the burning of the contents aided by heat coming through window openings from adjacent buildings, and so soon as the building yielded at one pillar or beam the whole structure followed, crushed by its own weight.

A similar instance of the destruction in a single hour of a great London warehouse, fire-proofed like the mills with arched brick floors on iron beams, but filled with combustibles, was described to me by a most competent eye witness.

These often quoted failures under severe test of so-called fire-proof warehouses and other structures had led me to be skeptical as to the enduring quality of such structures when filled with the exceedingly inflam-

*My information may be defective but I have been unable to learn that there was in the burned district of either Boston or Chicago a single building which could be classed as thoroughly "fire-proofed" in comparison with as approved American fire-proofing as we understand the term to-day.

able contents of a cotton mill, and I questioned many parties closely in the effort to learn the teachings of experience, for out of the hundreds of fire-proofed factories in Lancashire, some of which have been in active operation for more than forty years, there surely must be facts enough developed to serve as something of a guide.

I sought information from well informed practical men in Manchester, Oldham, Rochdale, Bolton and elsewhere, and asked whether or no fire-proof cotton mills had proved to be fire-proof, and asked each whether he could not recall some instance where, from the whole contents of a first-class fire-proof room being in flames, pillars or beams had yielded or floors fallen.

I could not learn of a single case.

I asked the manager and also the chief surveyor of the leading insurance company making a specialty of textile factory risks, whether it had ever happened that a fire originating in a lower story had, by making a breach in the floor passed into the stories above. They could name no case where this had happened by failure of a fire-proof floor.

One case was named where in such a mill fire had passed through the door into the stair tower and from the stair tower into stories above, and in another case fire had run up an open and unprotected elevator well. In another case flames issuing from a window of a room in flames had been blown into a window of the room above and this set its contents on fire.

In none of the above cases was the structure itself badly injured, and as an illustration of how much fire this style of structure can stand, a man who was an eye witness cited the case of Abram & Brierly's mill, where some half dozen years ago there occurred a fire in the second story mule room of a four-story mill, which spread over the whole room, spoiled all the mules, burned up most of the bobbins on the creels, and was finally put out by hose streams played in through windows after raging for two hours. The pillars, beams, and brick ceiling were, so he said, found uninjured after the fire and the fire was not communicated to the story above.

The only case where a fire-proof floor fell, of which I could anywhere learn, was related to me by Mr. Alfred Tozer, Chief of the Manchester Fire Brigade. This occurred at Windsor's Spinning Mill, Manchester, about six years ago; in a six-story mill. The two top floors were wrecked by fire, and the lower ones crushed by the debris, and a portion of the outer walls also fell. On inquiring into this case still further the fact was developed that this was an old mill which as originally constructed had thin wooden floors. These timber floors were afterwards replaced by brick arches on iron beams, and it is fair to presume the mill was less strong than one built fire-proof in the beginning.

As I have already stated, it was at one time common to build cotton mills in which the floors were all fire-proof, but the roof not so. There have been numerous cases where such roofs have been burned off, with nothing but water damage resulting to the stories below.

I take it that all this simply indicates that there is not ordinarily contained in the card room or mule room of the ordinary spinning mill

equipped with English machinery, a sufficient amount of fuel to heat the unprotected iron up to the point of rupture or to warp or expand it beyond the holding power of the masonry.*

And I also take it as demonstrating that cast-iron beams and pillars are not quite such treacherous building material as some persons would have us believe.

This testimony as to the safety against fire of these heavily loaded unprotected pillars and beams with uncovered bottom flanges is very comforting and reassuring in considering the merits of those American fire-proof office buildings in which the iron is carefully encased in tile with an air space.

The most clear headed fireman whom I chanced to meet during my trip was the Chief of the Manchester Fire Brigade, whose experience in the London and Manchester departments covers thirty or forty years. I put to him the question: Do you consider "fire-proof" mills fire proof? and he replied substantially that *whether fire-proof or not was merely a question of the amount of combustible contents.* That in his judgment and experience the spinning and even the carding rooms did not usually contain fuel enough to heat the mass of the floor system to the point of wrecking, but that if these were to contain the same proportion of stock as in a mixing or blowing room he ventured the opinion that the building would go down. He said he had seen fire-proof storehouses quickly succumb, and that he felt his life was safer fighting fire in a structure with timber floors, than in a fire-proof structure.

The English fire-proof mill has undoubtedly the advantage in freedom from vibration due to the great weight and inertia of its floors, but after all that I was able to learn as to the safety from fire with this class of structure I hold very strongly to the opinion that between a "fire-proof" mill with unprotected iron work and without automatic sprinklers (and in point of fact English fire-proof mills are very rarely equipped with sprinklers), and an American slow burning mill like Fig. 1, without holes in its floors, unprotected by any plastering on wire lath, but thoroughly well equipped with a good automatic system sprinkler, which is well cared for—both mill and contents are safer from destruction in the latter case.

COMPARATIVE COST OF INSURANCE OF FIRE PROOF MILLS.

It is difficult to form an opinion based on the insurance rates as to the relative safety of fire-proof mills, as compared with mills of the American type for the reason that in England there has been but little experience with the solid timber floor as compared with the inferior joisted wooden floor, and that the conditions of underwriting have been different. From what I gathered from both manufacturers and insurance men I understand the current rates on thoroughly first class standard cotton spinning mills, without automatic sprinkler protection and with only ordinary safe-

*The English carding engines are composed almost wholly of iron, moreover there is less woodwork about the English fly frame than in the ordinary American one, and in a mule room the amount of cotton in process is small per square foot of floor.

guards, to average about as follows, sharp competition having recently greatly forced down the rates:*

Net cost per thousand dollars insured per year.

Fire proof mills.	Building about $1.25	Average of plant about	$2.10
	Contents about 2.50		

Non fire-proof mills with thin board floors and joisted construction, about - - - - - - - 15.00

Thus it costs about seven times more to insure the non-fire-proof structure with joisted floors.

The insurance rate covers something beside the fire hazard, viz.: the cost of doing the business, so that the relative safety of the fire proof type must be very much greater than this proportion of about 7 to 1, and again even at this small comparative rate the fire proof mills are sought for by underwriters as much more profitable insurance than the mills with joisted floors at the higher premium.

In the New England Mutuals the net cost to the manufacturer for insuring an ordinary first class standard cotton mill with plank floors and without automatic sprinklers has averaged, per $1,000 per year, about $2.50, or substantially the same as for the English fire-proof mill. This low cost has, however, been in large part due to more economical methods of administration.

BRICK OR CONCRETE FIRE PROOF FLOOR VS. FIRE PROOFED TIMBER FLOOR.

First, although for mill work this will seldom be the case, assuming it to be desirable to build a "fire-proof" structure, then from all that I was able to learn as to safety of this English fire-proof construction, I incline to the belief that for a mill with 10-foot bays and 21-foot beams having its stairs and elevators enclosed by fire walls; a "standard American mill-floor," containing no belt holes, made of 4-inch spruce plank with 1¼ inch hardwood top course and ¾ inch of mortar between, and with the underside of plank and exposed faces of beams plastered upon "wire lath" or "expanded metal lath," *that such a floor will endure as fully fierce a fire as either of the types of fire proof floor illustrated in figures 5 to 12*, and that should it yield in one spot there is far less chance of this break involving the whole structure in ruin, since the weight supported by the pillars is much less. Floors thus protected by metal-lathed plastering have been in common use for a dozen years in the picker rooms of some of our American cotton mills.

Guided by experience with mills of the American type, well equipped with fire apparatus, we may say that places are rare where "fire-proofing' is really needed; because automatic sprinklers afford even greater safety

*As an item of information which may strike those not familiar with underwriting as strange, it may be remarked that experience shows the under-writer's hazard or ratio of fire loss to value is very much greater in even a neat and thoroughly well constructed slow burning cotton mill than is the hazard of a flimsily constructed wood tenement block crowded with careless and ignorant tenants and with numerous kerosene lamps, stoves and tobacco pipes.

and can be provided at half the cost of even a safe coat of wire lathed plastering.

For the few places like picker rooms or drying rooms or varnish rooms or other special hazards where it is well to make safety doubly sure, the writer believes that the protected timber construction would be equal or superior to the iron ribbed brick arches. And we may venture further and say that for fire proof office buildings, for laboratories or special industries where the interruption to business by fire is as disastrous as the destruction, that for all these cases we believe the American timber floor protected by mortar and plastering as above mentioned, would prove fully as safe against fire as the English brick or concrete flooring, or the better (because lighter) American fire proof floor of hollow brick or terra cotta.

The objection to the solid plank floor for office, school or hotel architecture thus far lies in its sonorous drum head like quality which sometimes transmits with inconvenient distinctness the noise of footsteps above it into the room below. It is believed, however, that this objection can be overcome by suitable precaution when building.

And although the several excellent fire-proof brick buildings in the vicinity of Chicago Board of Trade may well serve as models for 13 story office buildings in the heart of a great city, I believe there is a broad and comparatively unworked field of usefulness for the far cheaper office building, or especially the warehouse, of "mill construction" protected by plastering on wire lath.

A floor like that shown in Fig. 7 weighs about 115 pounds per square foot, while the standard American timber floor shown in Fig. 1 weighs all complete about 25 lbs. per sq. ft. and if for a 5-story cotton mill we take the ordinary permanent every day load of structure and machinery alone, excluding for the present the occasional loads of snow, extra stock, etc.; then for a mill with 10-foot bays and 21-foot beams, the loads upon pillars will be

	English Fire Proof Mill.	American Slow Burning Mill. Ordinary Construction. As in Fig. 1.	American Slow Burning type with addition of ¾ inch of mortar between floor boards and plank and 1 inch of plastering on metal lath.
	Tons.	Tons.	Tons.
5th Sto.	15	3	4
4th	30	8	11
3rd	46	13	18
2nd	62	18	25
1st	78	23	32
Bsmt.	88	29	39

This comparison shows a striking difference. In the upper half of a mill, where experience shows by far the greater part of our destructive fire to originate, the load borne by the pillars averages three times as great in the English fire proof structure as for a mill of the American type, made (as I believe it could be) equally fire proof, by the addition of a little mortar and plastering.

There is unquestionably some *inconvenience in a factory building* in applying this plastering to beams to which shafting hangers may have to be attached or new attachments made. In breaking the plastered surface for any new attachments particles of the grit may sometimes get detached and into bearings of the machinery, and often the convenience of screwing things into an uncovered wood ceiling will be missed.

VALUE OF PLASTERING ON WIRE LATH AS A MEANS OF FIRE-PROOFING.

The statement made a few lines back that probably a solid plank and timber floor protected by plastering upon good metal lath would go uninjured through as severe a fire as the English brick-arched mill-floor on iron beams, must so far be understood as a matter of opinion. The opinion is well grounded and is held by experts of high standing. I have not been able to learn that a fierce fire has as yet happened in a mill under such circumstances as to put its utmost endurance to the proof. Probably as severe a practical test as any was that at the new building of the Harvard Medical School. This structure is modelled after the best type of American mill construction, with mortar between top flooring and the plank and with ceiling fully protected by wire lath and plaster. Fire caught in a pile of rubbish one night in the amphitheatre just as the fitting up was about complete and gained what in any other type of structure would have been full destructive headway; the exposed woodwork was about all consumed and the plastering heated hot enough over a considerable space to burn off the soot which was at first deposited, yet the plastering withstood this heat perfectly and the timber behind it was uninjured in the slightest.

At a rather small yarn drying room connected with the dye house of the Nashawanuck Mills a fire occurred one night a few years since which completely consumed the yarn and the wooden frames on which it hung. The wire lathed plastering held on perfectly and protected the wood so well that in removing the plastering the plank was found only very slightly scorched or discolored by the heat transmitted through. Two years since I witnessed the firing of a small experimental building in which the wire-lathed plastering withstood a very fierce heat for half an hour without peeling off so as to expose the wood-work to the slightest degree. The test is detailed in the foot note below.*

*TESTS OF RELATIVE FIRE RESISTING QUALITIES OF COMMON LATH AND PLASTER AND WIRE LATH AND PLASTER.

CLINTON, MASS., Sept. 12, 1887.

Experimental buildings, each 2-story and about 8 feet square by about 18 feet high.—Buildings are roofed over but not boarded outside of the studding.

Buildings exactly alike so far as can be seen, (except studding is closer on wire lath building). Plastered two coats,—good ordinary job,—last coat four days old and yet damp. Rainy day to-day, thus making laths rather wet. Fuel in each building is of the same kind and amount, consisting of 6 bbls. shavings, 3 bbls. of pine blocks, nine broken empty barrels, and a gallon or two of benzine.

Time after
ghting Fires.

0 — Lighted fires in both buildings at same time. Both blazed fiercely from the start,—draft excellent,—conditions alike for each.

The picker room ceilings of our American mills have in the past often been tinned (*i. e.* covered with sheets of tinned iron) as protection against ignition. Wire lathed plastering presents the very great advantage over tin as a covering for the beams and wood work that by its porosity it permits the moisture to escape from the wood and thus does not induce dry rot.

That the lime mortar itself exerts no injurious influence on the wood may be inferred from the rarity of decayed wooden laths in any but the dampest and most poorly ventilated situations.

FIRE-PROOFED PILLARS.

A cheap compact fire proof pillar is the one thing needful to complete our American fire-proofed timber-floored mill. Ordinarily in those rooms where special hazards have called for the wire-lathed-plastering of ceilings and beams, the pillars have been made of uncovered cast-iron. The English fire-proof mill has its much more heavily loaded pillars also of bare cast-iron. So our structure with plastered timber floors is none the less fire proof in comparison, as regards pillars..

The reasons (though in a much less degree) which make heavy timbers preferable to iron girders, also makes the use of timber pillars desirable. A round eight inch Georgia pine pillar which was put in to safely carry its load with a factor of safety of *five* might be burned and charred in to the depth of 1⅜ inches over its whole surface, thus reducing its diameter to 5¼ inches, and still be left strong enough to temporarily carry *double* its regular load, or to stand up until the fire was over and props could be put in to relieve it.

Wooden pillars in extra hazardous places in American mills are sometimes tinned for fire protection. This is of doubtful merit unless the pillar is already so very thoroughly seasoned and so situated that dry rot may be considered out of the question.

8 min.	Three-fourths of all plastering on ceiling of wood lath building fell off.
9½ min.	All plastering from ceiling wood, lath building now off.
14 min.	Wood laths burned off in spots and flames have burst through the ceiling.
23 min.	During all this time fires in both buildings have been raging with very nearly equal fierceness, but as yet the wire lath building is practically uninjured. Fire is a very fierce one, and a man cannot possibly stand nearer than 8 feet to it without being scorched. Added 2 bbls. full of pine blocks and 4 empty bbls.
25 min.	Plastering on wire lath yet unbroken, but the small wooden furrings are beginning to smoke from heat transmitted through plastering.
27 min.	First glowing coal on furring for wire laths noticed. This comes from heat transmitted through the plastering..
28 min.	Notice that skim coat has started to shell off from side walls in two small places.
31 min.	Studding and furring beginning to blaze in several places from heat transmitted through the plastering which still hangs on Ceiling has not fallen at all yet.
	Finished experiments and put out fire.
Conclusion.	Wire lath resisted four times as long as wood lath, and at end of this time the plaster still hung on well to the meshes of wire, completely covering the wood from direct action of flames.

The patent fire proofed wooden pillars are bulky and expensive, encasing by tile and plastering is extremely bulky, and even a plastered pillar has its diameter so increased as to become inconveniently large for many places about a shop or factory.

Expanded metal lath can undoubtedly be so laid on a round pillar that a very neat job of plastering can be done, but the objection then comes, that in a factory this plastered surface would be almost sure to be chipped.*

In discussing the merits of plastering on metallic lath and in advocating the merits of American mill construction for warehouses and public buildings, we have drifted a little off the track of our direct comparison between English and American mills.

COMPARATIVE COST OF THE TWO TYPES OF CONSTRUCTION.

This is the most interesting of the comparisons and the key to the situation.

A prominent English mill architect made me this statement "It costs no more more money to build a fire-proof mill, with all floors and roof made of solid brick arches supported on iron beams in England that it costs to build a mill with standard solid plank and timber floors in America."

This statement at first astonished me. I thought the Englishman's patriotism outran his data. So we sat down and he proceeded to convince me. First by a rough estimate in detail of the main items, next by direct reference to contracts for a new and thoroughly first-class 80,000 spindle mill which I had visited a few days before, and later I confirmed these items in a general way by information from other architects and from the adjuster of a large insurance company.† It thus appeared that we could rely upon the statement that with the present very low price of iron a 4-story (and basement) mill of size to contain 80,000 spindles, constructed with brick arched fire proof floors throughout and also a fire proof roof, can be built exclusive of foundation for about *62 cents per sq. ft. of floor.*

(In computing this floor area taking outside dimensions of mill and counting the full basement story but not counting the roof, or what amounts to the same, excluding the basement and counting the fire proof roof as a floor.)

The cost of the floors alone including all pillars, rolled girders, brick arching and concrete filling and including a top floor of boards with its joist is...... ....*about 36 cents per sq. ft.*

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*It would seem that after a little experiment some cheap tough semi-porous skin to cover this plastering might be found which could be applied up to a height of 5 feet above the floor, preventing chipping while still not confining the air or moisture so as to produce dry rot. Perhaps two thicknesses of light cotton duck rolled around and sewed and glued on would answer in some cases and could be painted to look very neat and still retain sufficient porosity.

†Laxton's Price Book is worth a mention in this connection as an annual publication for the use of engineers and architects, which has now reached its seventy-third edition. In handy form for reference it contains price lists of almost every conceivable article used in building and valuable estimates of costs of labor on all sorts of mechanical work. American engineers and architects would most gladly welcome a similar publication.

And a concrete floor (similar to Fig. 12 but somewhat lighter) built with steel joist and of a weight and strength considered amply sufficient by some of the best architects, can be built for about 8% less.

I have mode an approximate estimate of the cost of a similar brick-arched mill-floor in New England under present prices, and find that including beams and pillars the floor system would cost......... *about 80 cents per sq. ft.*

The mill walls of the English type, if built here, would not differ very much from the ordinary American wall in cost.

Six years ago the average cost appeared to be about 90 cents per sq. foot (probably including foundation) according to a paper by Mr. Atkinson, who while visiting Lancashire made some enquiries on this point.

It is very rarely that even a large and wide 4 or 5-story American mill with timber floors is built much under .... *70 cents per sq. ft. of floor.*

The cost of the floor alone, including all top floor, plank and beams, wooden pillars, iron caps and pintles may at present prices be taken at.................................... *about 28 cents per sq. ft. of floor.* Timbers cost very much more in England and thus a floor of this type there would cost not far from.......................... *40 cents per sq. ft*

The total cost per square foot for a large wide building will of course be very considerably less than for a small or narrow one by reason of the smaller proportion which the cost of the outside wall bears to the whole.

The remarkably low cost of the English mill in comparison with the American mill can be best understood by a comparison of the cost of some of the structural materials.

	In England near Manchester.	In New England. near Boston.
Rolled Iron Beams per pound	1.4 cents	$3^2/_{10}$ cents.
Cast Iron Pillars with ends squared up per lb.	1¼ cents	2¾ cents.
Timber and labor for plank floor per M. feet Board Measure. Average for Beams and plank.	$53.00	$31.00

The following comparison gives in a nut-shell the whole story for the almost universal adoption of two such radically different types of structure in the two countries:

Cost per square foot of floor.	In England.	In New England.
Standard English type of fire proof Mill Fig. 8.	about 62 cents.	about $1.18 cents
Standard American type of slow burning Mill Fig. 1	about 68 cents.	about 70 cents.

We thus see that in England they can build the mill with the fire proof masonry floor cheaper than they could with our style of timber floor, and that in New England the mill built with fire proof floors would cost double that of the mill building having our standard timber floors.

As to the total cost of the fire proof mill and its equipment with machinery for spinning medium counts, from various sources I gather that

this averages about five dollars per spindle. It is to be borne in mind these are mills without weaving or *yarn mills* only.

Passing from spinning to weaving mills, we may take time to say a word about the saw-tooth roof which was first devised and used in England about sixty years ago. This although but rarely used in this country where the Monitor is the common type, is almost the only style seen in the weaving sheds in England or in the newer one story mills about Crefeldt, the textile centre of Rheinish Prussia.

There can be no question but that this with the glazing facing the north, gives the best lighted room that it is possible to obtain. As seen from the street these one story mills with saw-tooth roof look odd indeed, for often there is not a single window in all the four walls of the building, the light coming solely from the roof. And as these walls are carried up all around to a straight line at the full height of the peaks of these roofs, the serrated roofing is not seen from the street unless looked down on from above.

There are a number of these roofs down about Philadelphia, and the weave shed of the Planet Mills of Brooklyn was recently rebuilt with this kind of roof, replacing a former one of the same kind destroyed by fire. Almost the only one that we recall in Massachusetts is that over a part of the Farr Alpaca Company's works at Holyoke. The general objection in this region appears to be fear of trouble from snow. None of those which I have seen either in this country or abroad have combined the good features of solid plank and timber, American mill roof construction with the iron channel-shaped girder also forming a gutter and some other features seen in the saw tooth roof built by the best English architects, and I venture the opinion that a saw-toothed roof may yet be evolved which will meet the requirements of our winters may be of unlimited width and give a "light" as good as all out of doors.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF ST. LOUIS.

337TH MEETING, DECEMBER 3, 1890. ANNUAL MEETING:—The club met at 8:15 P. M., at the Elks' Club, President Nipher in the chair, and twenty-four members and two visitors present. The minutes of the 336th meeting were read and approved. The Executive Committee reported the doings of its 99th meeting.

The Secretary presented his annual report.

The treasurer made his annual report which was referred to the Executive Committee to be audited.

The Executive Committee made their annual report.

The following standing committees reported:

Report of the committee on monument to James B. Eads.—Col. Meier reported that they were making satisfactory progress and were meeting with very general encouragement not only in this city but throughout the country.

Report of the Committee on Smoke Prevention—No regular report was presented, but Col. Meier stated that the committee was still at work on the question.

Report of the Committee on Local Data—The committee reported that the papers were now ready for publication, and recommended that they be published.

Report of the Library Committee—Mr. Seddon reported what had been done for the past year.

Report of the Committee on Permanent Quarters—Mr. Holman reported that in accordance with instructions they had considered the question of immediate removal from the present quarters. There were two propositions: 1st. To rent a larger room for library and meeting room together. Such a room could be got in the Odd Fellows' Building for $40 per month; 2d. To retain the present library and meet at Mercantile Club, Odd Fellows' Hall, or elsewhere. A full discussion of the subject followed by Messrs. Meier, Blaisdale, Seddon, Johnson, Holman, Burnett, Moore and Ockerson.

Moved and carried that the Executive Committee be authorized to rent the Odd Fellows' room for a year and have it fixed up.

Moved and carried that the report of the Local Data Committee be referred to the Executive Committee for publication with power to act.

The Committee to make Nominations reported the following nominations for officers for 1891:

President—Geo. Burnett.

Vice-President—N. W. Eayrs.

Secretary—Arthur Thacher.

Treasurer—C. W. Melcher.

Librarian—J. B. Johnson.

Directors—F. E. Nipher, S. Bent Russell.

Members of Board of Managers, Association of Engineering Societies—J. B. Johnson, J. A. Seddon.

Owing to the lateness of the hour Mr. Seddon only gave a short abstract of his paper on the "Economic Dimensioning of Settling Reservoirs," and the paper itself was laid over to the first meeting in January.

Moved and carried that the Committee on Conference with the American Society of Civil Engineers be discharged.

Prof. Johnson stated that Prof. Thurston objected to the references made in Prof. Johnson's paper on "Aerial Navigation." In support of what he had stated

in his paper Prof. Johnson read some further paragraphs from Prof. Thurston's paper in the Forum.

The papers announced for the next meeting (December 17th) were: "President's Address," F. E. Nipher; "The Construction and Operation of Cable and Electric Railroads," Mr. Kebby.

(Adjourned.) ARTHUR THACHER, Secretary.

ANNUAL REPORT OF THE SECRETARY.

To the Members of the Engineers' Club of St. Louis:

GENTLEMEN:—The records of the Club show the following statistics for the past year:

The members of the Club have met together on twenty-two occasions, as follows: Nineteen regular meetings, one special meeting at which Mr. Mendenhall addressed the Club, one banquet in honor of Mr. Mendenhall and one informal supper to celebrate the twenty-first anniversary of the Club. Nineteen meetings have been held at the Elks' Club, two at Washington University and the banquet was held at the University Club. President Nipher occupied the chair on nineteen occasions and Vice-President Burnett on three. The total attendance of members was 6[illegible]6, or an average attendance of 30. The total number of visitors present was 97. Twenty-two papers have been read by the following members: Messrs. Perkins, Crow, Dudley, Connor, Beahan, Long, Nicholson, Smith, Frith, Schmitz, G. A. Brown, C. I. Brown, Petitdidier, Sherman and Profs. Johnson (three), Potter, Kinealy, Woods, Brown and Nipher. Addresses have been given by Mr. Mendenhall and Ex-President Meier. One evening was devoted to the report of the Committee on Local Data. There was a total of 124 remarks or discussions on the papers presented.

Twenty-two new members have been elected, while the Club has lost twelve members from its rolls, making a net gain for the year of ten. The losses include eight resignations, three dropped for delinquency and one death, that of Mr. Charles P. Mitchell. The present roll of the Club shows that we have 131 resident members, 47 non-resident and one honorary; total, 179.

Unfortunately for the Club, Mr. Wm. H. Bryan, who for the past four years has so ably filled the position of secretary, has been obliged to resign from that office, owing to his removal from the city.

From the above statistics it will be seen that the Club has passed its twenty-first birthday, and now contains the names of 179 members on its rolls, the largest number since its organization. While the average attendance at the meetings is the same as in the preceding year, the number of meetings has been greater and the number and character of papers and discussions show the continued interest, and give promise for the future prosperity of the Club. Respectfully submitted,

Dec. 3, 1890. ARTHUR THACHER, Secretary.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

To the Members of the Engineers' Club of St. Louis:

GENTLEMEN:—During the past year the Executive Committee have held twenty meetings. Eight papers have been approved for publication. Sixty-five bills have been approved for payment. The total amount of bills approved for payment is $1,528.86, divided as follows:

For the Journal	$ 540.76
For rent	369.00
For printing	204.85
For salary	170.00
For banquet	95.95
For furniture	86.70
For miscellaneous	61.60
Total	$1,528.86

Twenty-two applications for membership have been examined and approved. Eight resignations have been accepted and three have been dropped from the rolls for delinquency.

The programme for the ensuing year is nearly complete, and members desiring to present papers are requested to give early notice so that proper notice may appear in the printed programme.

The papers already received arranged in the order of the probable dates at which they will be read are as follows:

First meeting in January—Economic Dimensioning of Settling Reservoirs, J. A. Seddon.

Second meeting in January—Flood Control in the Lower Mississippi, Prof. Johnson.

First meeting in February—Some experiments to determine the Strength of Vitrified Sewer Pipe, Prof. M. A. Howe.

Second meeting in February—Specifications and What Should be in Them, Prof. Kinealy.

First meeting in March—Brick-Making Machinery, N. W. Perkins, Jr.

Second meeting in March—Accurate Measurements in Laying out Towns, Prof. Humphreys.

First meeting in April—Notes on Railway Locations, John H. Curtis.

Second meeting in April—Practical Hints on Cement Testing, P. M. Bruner.

First meeting in May—Studies on the Dynamo, Prof. Nipher.

Second meeting in May—

First meeting in June—

First meeting in September—

Second meeting in September—

First meeting in October—Use of Electricity in Coal Mining, W. Farnham.

Second meeting in October—The Temporary Low Service Pumping Plant, St. Louis Water Works, J. A. Baird.

First meeting in November—The Pollution of the Hudson River, Prof. Brown.

Second meeting in November—

First meeting in December—Tunnel Timbering in Soft Ground, F. W. Abbott. Annual Reports.

Second meeting in December—President's Address.

The Committee would remind the members that their earnest co-operation both in presenting papers and helping to secure addition to our membership are necessary for the continued success of the Club.

Respectfully submitted,

F. E. NIPHER, President,

Dec. 3d, 1890. ARTHUR THACHER, Secretary.

338TH MEETING, December 17, 1890.—The Club met at 8:10 p. m. at their room in the Odd Fellows' building, President Nipher in the chair, and fifty members and five visitors present. The minutes of the 337th meeting were read and approved. The executive committee reported the doings of its 100th meeting and announced the result of the ballot for officers. Total votes cast 101, the officers elected receiving votes as follows:

For President—George Burnet, 99.

For Vice-President—N. W. Eayrs, 99.

For Secretary—Arthur Thacher, 100.

For Treasurer—Chas. W. Melcher, 100.

For Directors—S. Bent Russell, 99; F. E. Nipher, 101.

For Librarian—J. B. Johnson, 101.

For Managers—J. A. Seddon, 98; J. B. Johnson, 97.

Col. E. D. Meier read a memoir of the late Thomas J. Whitman, a charter member and ex-president of the Club. Moved and carried that the memoir be published in the proceedings.

President Nipher announced the officers elected for 1891, and called on Messrs. Meier, Holman and Moore to escort the newly elected president to the chair.

Mr. Burnet took the chair and called on Prof. Nipher for his address.

The retiring president, Mr. F. E. Nipher, then delivered the annual address, giving an exposition of the condition of electrical industries in St. Louis:

Commercial electric lighting in St. Louis began in 1873, with the lighting of Conrad's brewery by Chas. Heisler. At that time it was generally believed that a general system of illumination by electricity was impossible.

The Heisler Electric Lighting Company, of St. Louis, have established seventy central stations, with a total lampage equivalent to 60,000 16-candle lamps. The Municipal Electric Light and Power Company are now operating 3,300 arc lamps, of which 1,400 are furnished to private consumers. These lamps are operated in 61 circuits, the longest of which is 21 miles, and carries sixty lights. The total length of the line is about 1,000 miles and the area covered is about fifty square miles. The area which may be said to be illuminated is about thirty square miles. The lights are operated by thirty-two dynamos. The same company operates a Heisler incandescent plant equivalent to 5,000 16-candle lamps, on 150 miles of line wire.

The Laclede Gas Light Company also operate a Heisler plant for alley lighting, having 814 32-candle lamps, operated in four circuits from two dynamos. The lines from one dynamo are each about twenty-five miles long, from the other about sixteen miles. The total length of the four circuits is eighty-six and four-tenth miles, and the area lighted is four square miles. The same company operates a Brush alternating system for indoor lighting. This system is also operated in four circuits, a total length of thirty-five miles. The system employs forty-one converters, with a capacity of 1,245 sixteen-candle lamps. The Missouri Electric Light and Power Company have about 1,225 converters in use, with a capacity of 35,000 16-candle lamps. There are twenty feeders leading from the station, of which the longest is five miles.

The same company operate 150 miles of alley lamps, requiring about half of capacity of one of their dynamos, of which there are eight. These alley lights are run in series multiple, in thirty-five lines of twenty lamps each, between three mains at a potential difference of 1,000 volts. There are 700 of these lamps, covering an area of twelve square miles.

There are about fifty isolated plants in St. Louis, having in all about 28,000 lamps and representing a capital of $252,000. The largest plant is at the Exposition building, which has 6,000 lamps.

The Union depot Railroad Company now operate fourteen miles of double track. At present eight compound dynamos are in use, each capable of delivering 100 horse power. When complete the plant will operate twenty-two dynamos. At present twenty-four motor cars are run during the day, and thirty-four motors and trail cars are used during heavy traffic. The Lindell Railway Company are also using electricity, but no information has been received from them.

Mr. H. M. Kebby then read a paper on "The Construction and Operation of Cable and Electric Railroads." Mr. Kebby compared in detail the cost of constructing equally well-built electric and cable roads. These figures showed a difference in favor of electric roads of $3,261 per mile. In regard to operating expenses in the examples cited, the figures showed a difference in favor of cable roads, the cost per car per mile for electric roads being 4.468 cents, while for cable roads the cost was only 2.441 cents. In conclusion Mr. Kebby thought that where the capital could be obtained for the first cost, and the traffic would warrant it, the cable would be cheaper in the end, and that the greater the traffic the more marked would be the difference.

In the discussion which followed, Col. Meier presented figures which differed considerably in regard to operating expenses from those in Mr. Kebby's paper, and thought that no fair comparison could be made without paying more attention to local conditions.

Mr. Seddon said that the cable roads had had a longer time to perfect their system than the electric, and judgment should be withheld to give the electric roads a chance.

Mr. Kebby stated that in view of the larger mileage and greater number of en-

gineers interested in the electric systems than in the cable, he thought the electric systems had had about as good an opportunity as the cable.

Mr. Ayer said that the electric companies had been crowded so in order to fill the great demand for electrical supplies that they should not be judged too critically as to what they could do when given a little more time.

Messrs. Holman and Bartlett gave some interesting figures as to operating cable roads, and Messrs. Burnet, Woodward, Moore and Wheeler also joined in the discussion.

The paper announced for the next meeting, January 17, was "Economic Dimensioning of Settling Reservoirs," by Mr. J. A. Seddon.

Adjourned. ARTHUR THACHER, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

OCTOBER 6, 1890.—The meetings of the Society resumed on this date, after the summer recess. Meeting called to order by President Mason, at Hotel Ryan at 8:15 p. m. 13 members present. Minutes of June meeting were read and approved.

Communication read from the Western Society of Engineers, relative to sending a committee to meet the committee of other societies in Chicago, Oct. 14th, to arrange plans for the holding of an Engineers' Congress in connection with the Columbian Exposition in 1893.

It was moved by Mr. Powell that it is the sense of this Society that such a Congress be held and this Society endorses the plan. Carried by vote.

The committee appointed were Messrs. Elmer, Rundlett and Curtis, the President being ex-officio also a member.

President Mason gave some interesting information regarding the foundation of Pier 1, of the St. P. & N. P. R. R. bridge at Minneapolis, on the Mississippi river below the Falls, reading from the report of Mr. Cappelen, engineer in charge of said work.

Mr. Munster gave some details concerning the foundations of the different highway bridges in St. Paul, over the Mississippi river, from which the following data are taken.

HIGH BRIDGE.

	TONS—2000 LBS.
Pier No. 21—Load on each pile, dead	9.4 tons.
" " " live	2.27 "
	11.67 "
Water at —8.	
Piers 22 and 23—Load on each pile, dead	9.2 tons.
" " " " live	1.6 "
	10.8 "
Pier 24—Load on each pile, dead	9.4 tons.
" " " live	2.27 "
	11.67

Average movement of pile, last blow—1⅝in.

Height of fall of hammer—34ft,

Weight ot fall of hammer—2000lbs.

Pier No. 25—East side—Load on each pile, dead	6.42 tons.
" " " " live	1.90 "
	8.32 "

Av. movement last flow W Pier—4¹⁄₁₆in.

" " " E Pier—3½in.

Height of fall—31ft.

WABASHA ST. BRIDGE.

Pier No. 2—Load on each pile, dead	12.1	tons.
" " " live	2.87	"
	14.97	"

Av. sinking, last blow—$1\frac{1}{8}$in.
Height of fall—24ft.

ROBERT ST. BRIDGE.

Pier No. 3—Average dead load per pile	15.3	tons.
" " live " "	2.00	"
	17 30	

Pier No. 4—About the same.

Average for other pier, dead	11.	tons.
" " " live	1.5	"
	12.5	

Mr. Toltz gave some information about the foundations of the new steel arch bridge over the Mississippi river at Minneapolis, also about the foundations of a proposed railroad bridge at same place.

Mr. Morris followed with a description of the foundations used at St. Cloud for the piers of the Great Northern R. R. bridge—and mention of the stone viaduct at Minneapolis.

Adjourned. GEO. L. WILSON, Sec'y.

NOVEMBER 3, 1890.—The regular meeting of the Civil Engineers' Society was held this evening at the Hotel Ryan. President Mason in the chair. 10 members present.

The minutes of the last regular meeting were read and approved.

The printed report of the proceedings of the Chicago meeting, of the representatives from the different Engineering Societies, held to consider the matter of providing headquarters for engineers visiting the Columbian Exposition in 1893, and also the plan of holding an Engineers' Congress in Chicago during the same year, was read and laid over until the next meeting for action.

Mr. W. W. Curtis read a paper upon Distribution Reservoirs for Water Works, and illustrated the same by drawings and engravings of a large number of works as constructed.

Upon motion Mr. Curtis was requested by the Society to prepare his paper for publication.

Adjourned. GEO. L. WILSON, Sec'y.

DECEMBER 1, 1890.—Meeting opened in Hotel Ryan at 8:25 p. m. President Mason in the chair. 9 members present.

The minutes of the last meeting having been read and approved, the matter of electing a delegate to the Columbian Exposition in 1893 was taken up. Upon vote Mr. Curtis was elected as the representative of this Society at Chicago.

Also it was moved and carried as follows:

Resolved, That this Society will raise by an assessment the sum of $50 toward the expense of the permanent organization of the Columbian Exposition Committee.

The subject of uniting with the Minneapolis society in joint meetings as suggested by that society, was then taken up and the following motion made and carried:

Resolved, That President Mason communicate with Prof. Pike the president of the Minneapolis Engineers' Club, and that it is the sense of this meeting that four joint meetings be held by the two clubs, alternating in each city.

And that President Mason be and is authorized to make such arrangements as may seem desirable to him for such meetings.

Adjourned. GEO. L. WILSON, Sec'y.

JANUARY 5, 1891.—The annual meeting of the Civil Engineers' Society of St. Paul, held this Monday evening, at eight o'clock, at Hotel Ryan. President Mason in the chair. Eleven members and one visitor present.

The minutes of the last meeting having been read and approved, the annual reports of the Secretary and Librarian were read, and upon motion accepted and placed on file.

President Mason made some remarks appropriate to the end of the year and the election of officers for the ensuing year was held with the following result:

President—S. D. Mason.

Vice-President—Geo. L. Wilson.

Secretary—C. L. Annan.

Treasurer—A. O. Powell.

Librarian—A. Munster.

Representative of the Society on the Board of Management of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES—C. J. A. Morris.

Auditor—to audit accounts of 1890—W. W. Curtis.

The literary exercise was a paper by Mr. A. Munster on "A Diagram and Formula giving the Strengrh of Columns according to Gordon's Formula by a shorter method."

Owing to the lateness of the hour the discussion was postponed until the next meeting.

Adjourned. GEO. L. WILSON, Secretary.

BOSTON SOCIETY OF CIVIL ENGINEERS.

NOVEMBER 19, 1890.—A regular meeting was held at the American House, Hanover street, Boston, at 19:40 o'clock. President Herschel in the chair. 57 members and 35 visitors present.

The record of the last meeting was read and approved.

Mr. Walter Jenney was elected a member of the Society.

The Secretary read the report of proceedings of the convention held in Chicago to consider the establishment of an Engineering Headquarters and the holding of an International Engineering Congress during thelcoming World's Fair in Chicago.

On motion of Mr. FitzGerald it was voted that the Boston Society of Civil Engineers join in the plan suggested by the convention for the purpose of establishing an Engineering Headquarters, and the holding of an International Engineering Congress during the World's Columbian Exposition in 1893, and that the sum of $250 be raised by subscription, to be opened by the Treasurer of this Society.

On motion of Mr. E. W. Howe it was voted that the Board of Government be requested to appoint a delegate to represent the Society on the permanent committee on International Congress and Engineering Headquarters.

Prof. C. Frank Allen opened the discussion of the evening with a paper on Roads and Road-Making. He was followed by Messrs. E. W. Howe, W. E. McClintock, A. F. Noyes, Thomas Aspinwall, and others of the Society, and Mr. M. Driscoll of Brookline, Mr. A. H. Kimball of Hingham and Mr. J. P. Prichard of Medford.

Adjourned. S. E. TINKHAM, Secretary.

DECEMBER 17, 1890.—A regular meeting was held at the American House, Hanover street, Boston, at 19:40 o'clock. Vice-President Freeman in chair. Fifty-four members and twenty-six visitors present.

The record of the last meeting was read and approved.

Messrs. Ellery C. Appleton, Alfred W. French, Eugene J. Spencer and Elton D. Walker were elected members of the Society.

On motion of Mr. Hodgdon the sum of $50 was appropriated for binding and other expense of the library.

Mr. Howard A. Carson gave an informal talk upon the Metropolitan System of Sewerage. With the aid of lantern views he described the work which had been done on the Brighton, East Boston, Winthrop and Deer Island sections and gave the costs of the same. He followed this talk with an account of the methods of tunnelling now being used under the Hudson river at New York.

Mr. F. P. Stearns, who was one of the commissioners appointed by the President to report a system of sewerage for the District of Columbia, gave a very interesting account of the plan recommended by the commissioners and the reasons which led to its adoption.

Adjourned. S. E. TINKHAM, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

DECEMBER 20, 1890.—The regular monthly meeting was held in the office of Messrs. Sizer & Keerl, Helena, Mont. Mr. W. A. Haven occupied the chair. There were present Messrs. de Lacy, Hovey, Foss, Kelley, Sizer, McRae and Keerl and Wm. H. Dearborn, member A. S. C. E. as visitor.

Minutes of previous meeting were read and approved.

The Secretary read the report of the committee appointed to nominate officers of the Society for the ensuing year and stated that he had issued the letter ballots for officers, in compliance with the directions of the Board of Trustees.

Mr. J. S Keerl made a verbal report for the committee appointed to select a representative of the Society to serve on the Permanent Committee upon Engineering Headquarters and an International Engineering Congress, to be held during the World's Columbian Exposition, 1893. He stated that the committee had selected for this duty Mr. Elliott H. Wilson, of Butte, and had received a letter from that gentleman consenting to serve, and that this selection had been reported to Mr. Weston, Secretary of the committee at Chicago.

The action of the committee was approved and the committee discharged.

Mr. Walter S. Kelley, chairman of the committee of arrangements for the Annual Meeting made a progress report, stating that the first day of the meeting would be spent at Marysville at the invitation of Mr. R. T. Bayliss, manager of the Montana Company, when an inspection of the mines and works of that company will be made. In the evening after the return from Marysville the Annual Meeting will be held, and later on a banquet at the Hotel Helena. It was moved and carried that the committee be continued with full power to perfect and publish a programme.

Mr. J. S. Keerl, chairman of the committee charged with the preparation of a memoir of Major Benjamin H. Greene, late president of the Society, submitted and read the same, which was approved, and motion made and carried that the committee be continued with instructions to have the memoir published in THE JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES and also to have it published in pamphlet form.

A paper by Mr. S. J. Jones on the "Arithmometre" was read by Mr. Finlay McRae, who demonstrated the advantages resulting from its use upon certain classes of calculations, on a machine kindly loaned by General George O. Eaton, Surveyor General for Montana.

This machine is of French invention and is capable of multiplying 16 figures in the multiplicand by eight figures in the multiplier and performs division with equal facility. It has been in constant use in the Mineral Department of the United States Surveyor General's Office for Montana, for about four years, mainly upon traverse calculations, and accomplishes results in much less time than is practicable by the use of logarithmic or traverse tables.

A vote of thanks was passed to General George O. Eaton for the loan of the "Arithmometre" and to Messrs. Jones and McRae for the paper read and the interesting illustrations given, proving the value of the machine in facilitating calculations.

The Secretary was instructed to communicate with Mr. S. J. Jones, requesting permission for the publication of his paper in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Adjourned. J. S. KEERL, Secretary.

WESTERN SOCIETY OF ENGINEERS.

DECEMBER 5, 1890.—The 275th meeting of the Society was held at its rooms, Wednesday evening, December 5, 1890, at 8 o'clock p. m., President L. E. Cooley in the chair and over 50 members and visitors present.

Reading of minutes of previous meeting was dispensed with and the Secretary reported for the Board of Directors the following gentlemen elected members of the Society:

Bertrand E. Grant, Henry W. Tuttle, Geo. B. Springer, Albert L. Eliel. Chas. W. Stewart, (November).

The following applications were filed: Wm. G. Potter, Chas. Lewis Harrison. James Berry Williams, E. R. Schnable.

The following resumed membership: E. J. Ward, B H. Bryant.

The President called for report of Nominating Committee but the Chairman, Mr. E. L. Corthell, stated that the Committee was not yet ready to report.

The following report of the Committee on Annual Meeting was read and unanimously adopted,

To the President and Members of the Western Society of Engineers:

GENTLEMEN:—Your Committee on Annual Meeting and Entertainment, begs to report progress and to make the following recommendations with request for your endorsement:

1st. That the Annual meeting be held at the Sherman House on Wednesday, January 7th, 1891; this being the date fixed by the constitution for holding the same.

2d. That arrangements be made for a Buffet Lunch with punch bowl and cigars

3d. That the cost to members attending be placed at $2.50.

4th. That music be made a feature of the programme, and that the Committee be empowered to secure the same.

5th. That the regular order of business be dispensed with and that the following programme, subject to revision, take its place:—Call to order at 8 o'clock; Minutes of previous meeting; Appointment of Tellers on Balloting; Secretary's Report; Teller's Report; Address, Retiring President; Collation; Address, President Elect; Address, Mr. Corthell; Address, Mr. Chanute; Address, Mr. Whittemore; Address, Mr. Butterworth; America.

Respectfully submitted,

JOHN LUNDIE,
W. J. KARNER,
H. C. ALEXANDER.

The President appointed the following delegates to the coming meeting on an International Engineering Congress, etc.: E. L. Corthell, O. Chanute, D. J. Whittemore.

Upon the request of Mr. Corthell as to what action had so far been taken by various Societies on International Engineering Congress, the Secretary read letters from the Engineers' Club of Philadelphia, the Boston Society of Civil Engineers, the Engineers Society of Western Pennsylvania, the Montana Society of Civil Engineers, the Canadian Society of Civil Engineers and others, which showed a very gratifying interest in the undertaking and the practical interest that all had taken action towards the securing of funds for the expenses.

Mr. Corthell reported that while in Mexico lately he had received assurances from English, Mexican and American engineers, that all will cooperate ween the matter is officially brought before them by the Joint Committee.

Mr. Corthell then presented the following resolution, with remarks explanatory of its object.

Resolved, That this Society will undertake to raise by voluntary subscription, $500—each member to be requested to subscribe $2.00, towards defraying the expenses of Joint Engineering Headquarters, which it is proposed to establish at the World's Columbian Exposition, to be held in this city in 1893; the subscriptions to be payable prior to May 1, 1891.

The resolution was unanimously adopted.

The Secretary read a letter from Mr. D. J. Whittemore, calling attention to the extensive Portland cement works recently established at Yankton, S. D., and asking what members had access to Standard Testing Machine, that he might send them samples for test.

The President then called upon Mr. Max E. Schmidt, who gave a description of the Multiple Dispatch Railway, the joint invention of himself and Mr. Silsbee.

Mr. Schmidt explained that as a large sized model was erected in his office and that a paper read in connection with it might be more interesting, it was moved and seconded that a special meeting be held at Room 567, The Rookery, December 10, at 8 p. m., for the paper and the discussion upon it.

The President next called for the paper of the evening, Dr. de Bausset's "Aeroplane," presented by Mr. Otis K. Stuart, Member of the American Institute of Electrical Engineers.

Aerial Navigation being a subject of immediate interest, the paper elicited considerable discussion participated in by Messrs. Corthell, Chanute, Williams, Winger, Kandeler, Guthrie and the President.

A full report of paper and discussion is postponed to await decision as to publication in full in the JOURNAL.

The thanks of the Society were tendered to Mr. Stuart for this interesting paper.

Adjourned. JOHN W. WESTON, Sec'y.

SPECIAL MEETING, DECEMBER 10, 1890.—The 276th meeting of the Society was held in Room 567, The Rookery, Chicago, Wednesday, December 10th, at 8 o'clock p. m., with 40 members and visitors present.

In the absence of the President, Mr. Benezette Williams was called to the chair.

The following report of the Committee on Nomination of Officers for 1891 was presented by Mr. E. L. Corthell, Chairman.

CHICAGO, November 25th, 1890.

PRESIDENT WESTERN SOCIETY OF ENGINEERS:
78 La Salle Street, City.

DEAR SIR:—Your committee for nominating officers for the ensuing year have the following to report:

At a meeting of the Committee, held at the Society rooms, November 25th last, we nominated for President, Charles FitzSimons and Robert A. Shailer, First Vice-President, Hiero B. Herr, John F. Wallace; Second Vice-President, A. J. Tullock, W. O. Seymour; Secretary, Treasurer and Librarian, John W. Weston; Trustee, O. Chanute and Fred Davis. Yours Respectfully,

E. L. CORTHELL, A. GOTTLIEB, S. G. ARTINGSTALL.

MR. O. CHANUTE:—Mr. Chairman. In moving the acceptance of the report I wish to add an amendment. The Committee on Nomination has followed the time honored practice, the unwritten law of the Society, that a president shall serve but one term. If I am to believe the expressed wishes of a large number of members with whom I have conversed on the subject, they desire to have an opportunity of showing their appreciation of the way in which the affairs of the Society have been managed during the past year by violating that unwritten law, and to have the opportunity of voting again for the gentleman who has presided over our deliberations for the past year. You know that the meetings of the Society have elicited larger interest; have been more numerously attended and have excited more public attention than any of those which have taken place for a number of years. I therefore offer this resolution, and I hope some of you will second it:

Resolved, That the report of the Nominating Committee be received and accepted, and that the nomination of Mr. L. E. Cooley for President be added thereto as a token of our professional esteem and our appreciation of his promotion of the welfare of the Society during his presidency—this year.

The resolution was seconded.

MR. RICHARD P. MORGAN:—Mr. Chairman. Before putting that motion I will say a word in the affirmative. I am very much pleased that such an amendment should have been made to the report. I have been absent and know very little of the proceedings in Chicago for the past month, but the resolution meets my views exactly. The Society has manifested a very gratifying vigor under the presidency of Mr. Cooley, and it seems to me that it would not only be a very proper compliment to him that his name should be added to the candidates, but altogether it places the Society in a position possible to extend the vigor of the past year, and for one I shall be very much pleased to see that done.

The motion to accept the report with the name of Mr. Cooley added as a candidate was put to vote and carried uuanimously.

A joint letter from General Charles FitzSimons and Mr. Robert A. Shailer was then handed to the Secretary, in which these gentlemen withdrew from the candidacy for President.

Upon the chair presenting the letter to the Secretary for action; Mr. Richard P. Morgan in appropriate remarks moved the acceptance of the letter of withdrawal o General Chas. FitzSimons and Mr. Robert A. Shailer from the candidacy for president. The motion was seconded and carried.

The chairman then called up Mr. Max E. Schmidt for the paper of the evening, "A Novel Multiple Dispatch Railway." In consequence of a cold Mr. Schmidt asked Mr. Silsbee, the joint inventor, to read the paper.

The paper attracted great interest, and the presence of a large working mode greatly assisted in the descriptien of details.

The discussion which followed was mainly in the line of developing details, and the invention evidently met with favor in the minds of the members present.

The paper and discussion will be given in an early issue of the JOURNAL.

Adjourned. JOHN W. WESTON, Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

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THE MODERN SPIRIT OF THE ENGINEERING PROFESSION.

RETIRING ADDRESS OF PRESIDENT L. E. COOLEY TO THE WESTERN SOCIETY OF ENGINEERS.

[Read January 7, 1891.]

The ordinances of the Society call for a review of engineering progress for the year of his incumbency by the retiring president. The important works in progress or projected were fully and ably presented at the last annual meeting by my immediate predecessor in office, and will no doubt, be adequately treated by the president of some other society, in the Association of Engineering Societies. In view of the ferment which is now working in the profession, a few thoughts indicative of the dominant spirit and the direction which it may take seem opportune.

I.

1. Engineering is "The science and the art of utilizing the forces and materials of nature."

The engineer is therefore broadly educated in the domain of exact knowledge. Principles must determine his methods as conditions are ever varying. Necessarily, his conceptions are creative in thought and purpose and their execution makes him an organizer and administrator; the public utility of his work makes him in a high, practical sense, an economist, statesman and philanthropist.

The projects of the engineer are diverse, limited in individual works, widely scattered territorially—greatly varying in physical conditions, resources and circumstances. He goes among many peoples, and deals with many classes—capitalists, merchants and politicians; the agents of trade, industry and transportation, and the employes of all grades who

execute his work. He is a more thorough cosmopolitan than the traveller, and a better business man than those whose economic ideas are based on how to save rather than how to spend. Like the husbandman, he plants for the future crop; even more, he changes the conditions to all future advantage while serving the present, and plans for the growth beyond his own generation. He is the one exponent of material progress, and his works are the lasting monumental indices of civilization.

2. Engineering naturally segregates in three grand divisions; as civil, mechanical and mining, and again subdivides into less distinctive specialties. Taste or circumstance may lead individuals in narrow lines, thus developing the expert and pushing out the frontiers of knowledge; but great undertakings involve many lines, call for men of large grasp, equipped in the broad field of the profession, even in its grand divisions, organizing specialists in the details.

In its earlier development, engineering was hardly more than an art, a trade acquired by example and experience, progressing slowly by small departures from precedent. Practical experience in the line of employment was a pre-requisite to responsible charge, and men were jealous of that acquired knowledge which constituted their capital account. So far as possible, it was a routine, the duplication of things already done, and the specialist was simply a narrower and more expert craftsman. New projects were quickly pronounced impracticable on superficial examination, or a grave and learned opinion, or judgment, was delivered, based perhaps on unrelated experience. The engineer never betrayed lack of confidence or positive opinion, never said I cannot tell until I ascertain all the facts, for the scientific and inductive era of his profession had not arrived.

The dominant spirit to-day is scientific, the application of principles, without much regard to precedent. Only conclusions derived by logical methods from exact data and applied to conditions which have been fully valued, inspire respect. Experience is also demanded, that experience in the application of forces and materials which give practical skill and confidence, but not in the nature of that precedent, which is too often a handicap under different conditions.

This change is but the spirit of the modern age, the crowding out of the old by the growth of scarcely forty years of marvellous development. Everywhere, we see works projected boldly and confidently that violate all precedent until the engineer does not hesitate to undertake any useful enterprise for which capital is to be had.

The profession has always had men clear in mind and purpose, wonderful men who have contributed largely to scientific progress, whose labors have endowed later generations. To some of these and to the leaven of West Point and Troy, we owe the fostering of technical schools with broad and masterful training in first principles. It is scarcely twenty years since these schools began to contribute largely to the profession. This generation is now coming into responsibility, is making itself felt everywhere, and under the leadership of the broad minded men of the older genera-

tion, we begin to see material departures in the time-honored policy of the profession, tendencies stimulated in no small degree by the growth and multiplication of the professional society.

3. The early engineer of this country was a species of scientific or skilled tramp with a precarious tenure of position measured by the work in progress. He furnished his employer with the skill of his trade without questioning public policy or the best solution; in other words, the engineer was a tool who assumed his employer to be responsible for his acts. The conscientious engineer was always industriously working himself out of a job, was in the position of the man who saws vigorously at the limb on which he sits.

Much of this character the profession retains to-day, but the growth of professional spirit and the enlightenment of the employer is working a change. The profession is losing its transient character, tenure of position is more secure and work in many lines is done throughout wide sections by engineers and firms from a central office or headquarters. The engineer is assuming more the position of counsellor, is more the executive factor in the conduct of large operations, is retained more as an advisor on the staff of industrial enterprises. All this gives stability, material rewards and independence, gives the engineer a fixed abiding place and makes him a factor in the community in which he lives, enables him to develope the social qualities which he needs, and leads to that pre-eminence enjoyed by our profession in older lands.

4. Every household has occasion to employ the physician, it is rarely that the lawyer can be escaped and at regular intervals the preacher may be heard. The architect is called in often enough to make his calling familiar. The labors of the engineer pertain to public works, to large enterprises requiring capital, and do not bring him into business relations with the general public. There are many doctors, lawyers and preachers, all fixed in habitation and easily identified, where there may be but one wandering engineer. His qualities and genius do not impress themselves on the general public. It is largely by localization and organization that the engineer may become an active, integral factor in shaping the spirit of the times and make himself usefully felt as a citizen.

The social organism grows complex, tends to a well ordered machine run on scientific principles. Great transportation agencies, enormous industrial developments, even the conveniences of business and of living, demand trained minds to plan and execute, and their management is increasingly intrusted to technical charge. The newer agencies of civilization require the highest attainment. There comes about therefore an increasing proportion of engineers in our complex, material growth.

This very complexity and the special training which it demands, throws the engineer into the position of promoter which he has so long enjoyed in older countries. After all, what citizen is more broadly and thoroughly equipped, can better understand what is feasible and how public convenience may be better served and methods cheapened—who shall be a better economist and statesman in this age of forces and devices.

II.

What are the duties of the engineer as a citizen and what is to be his future relation to the machine of civilization?

1. The engineer is a man of too much breadth, is too cosmopolitan, to organize anything in the nature of a professional trades-union, to go even as far as has the doctor, the preacher or the lawyer; but in his association unwritten laws of ethics will crystallise. the profession will broaden its interests and sympathies, he will become a factor which is recognized for the general good of the community and with public regard he may achieve those higher ambitions which are for the welfare of the state.

It is proper and commendable for doctors to promote measures for the public health, to establish boards of health and to regulate the practice of their profession—they even indulge in recommendations which appear to be actually in the interests of patients. Lawyers are not backward in suggesting legislation in regard to courts, legal procedure and a host of things which concern their profession. The engineer alone—at least, this has been much of the spirit of the past—refrains studiously from any action which might be construed as an interference with any established order however bad it may be.

2. Knowledge brings its responsibilities. It is common law that every man must to the extent of his power prevent crime, loss of property and accident and rescue from danger. In a broad sense, it is the duty of every man to exercise himself for the public welfare and particularly in those lines where his special knowledge and experience makes him more alert, than other men.

The labors of the engineer are broadly humanitarian, dealing with works of utility and convenience in a public sense, in which the element of safety is ever to be consulted. He may properly—nay, it is his duty—promote regulations which restrain ignorance and greed from imperiling human life or wasting the public funds; he may suggest organizations for the better conduct of public works affairs, and he may develop public enterprises which would otherwise lay dormant and direct them to a wiser end. In all these, individually and collectively, he may stop when those who are charged with the duty of acting have been adequately advised.

3. The duty and responsibility of the engineer in public and quasi-public enterprises, grow clearer with the advance of the profession. It is quite the custom to pass laws and ordinances which only a knowledge of the physical conditions to be ascertained later, can properly construe. Men, perhaps in ignorance and unmindful of the conditions, may make an interpretation which subverts the actual purpose of the law, may arbitrarily direct an engineering course which defeats the best results and is wasteful of the public funds.

If the engineer acquiesces or becomes a passive instrument, is he relieved of responsibility morally or even legally? You may face these questions some time and have to act. They are matters that it would be well for professional men to think more about.

4. Thirty-six years ago, the first engineering society was established

and it is but twenty-one years since the "Engineers Club of the Northwest" met as a social organization and for technical discussion. Nine years ago the club assumed a charter and its present name and entered upon that career of development in which the past year has been so auspicious. Organizations have been formed in nearly every large center and some of these have entered an association for special purposes. The time will come when all local organizations will be federated for all purposes which may concern their common welfare.

The Western Society has devoted the year largely to the discussion of questions of public interest. A committee is now laboring with the railway terminal problem; committees are engaged on bridge legislation and on regulations regarding the practice of sewerage and waterworks, committees are laboring on a national public works organization and on a model for the organization of municipal public works; a committee on federation of societies has developed some organic principles of union; a geodetic and cadastral survey for Illinois is the subject for another committee; a committee entertained the Iron and Steel Institute of Great Britain and Austria, and a committee has met gratifying success in promoting an International Congress of Engineers at Chicago in 1893. These committees evince the present spirit of the profession and the good work will go forward more easily as we grow in material resources.

5. The occasion demands little more.

I regret sometimes that the engineer is not more assertive of his prerogatives among men and console myself with the reflection that his broad comprehension of "forces and materials," the ever varying phenomena flowing from fixed principles, the inscrutable law which he recognizes behind all, makes him modest, makes him tolerant of the egotism and the petty strifes of men, the arrogance whose purse string is the patent of nobility.

Primitive man stood close to nature and with keen perceptive faculties rudely classified the dominant agents which he recognized, personified them as deities who directed his destiny—it was Thor, Woden, Saeter, it was Earth, the mother who fed her children. Science pushes back to more primary causes, gives names which mean the same for there is the same inscrutable mystery behind known things, the same immutable elements to which the generations have bowed as subjects. The engineer applies to man's purpose—for his convenience, his aid or his defense,—is the extreme of the primitive child of nature and yet the same, by his trained imagination and exact methods, interpreting the physical universe for the common good.

Nature has graven earth in a hieroglyph which he translates, telling the message in the name of the great forces of which he is the disciple. He is the one man who stands back close to created and creative things, himself a creator who makes this world tolerable to man—a priest of nature who makes it possible for men to have souls for the priest of the faith to save.

As we harness more fully the forces and make the materials subject, the social state becomes more completely an organic machine, men drop

into the grooves and thread the mazes, losing that individuality which preceded the great discoveries and inventions. Sooner or later the engineer will stand at the throttle of this machine and the world will need to know what manner of man he is.

THE MULTIPLE DISPATCH RAILWAY.

By Max. E. Schmidt, Member Western Society of Engineers.

[Read at a Special Meeting, Dec. 10, 1890.]

Of the many problems that have occupied the American mind, none has received more careful thought and closer study than that of providing means for the transportation of large crowds of people. The novel railway, represented in this model, deals with this problem, and by providing for the conveyance of passengers to their seats while the railway is in motion, obtains a carrying and seating capacity which will exceed that of any other device heretofore applied for the safe and comfortable transportation of passengers in populous cities.

The railway referred to is the joint invention of Mr. J. L. Silsbee, architect, of Chicago, and myself, and is secured by United States Letters Patents, with applications for European patents pending.

In the description which follows, the middle platform of the three will be referred to as the car, which is intended to have seats the whole length of the road, and the others as the outside platforms.

As will be seen from the plates and the model, the invention consists essentially of three continuous platforms, of which the middle one, or car, contains seats, and travels just twice as fast as the outer ones. This is accomplished by attaching the cars to movable flexible tracks resting upon the peripheries of wheels mounted upon such axles, so that as the wheels and axles run upon fixed tracks at a certain ratio of speed of the axles, the movable rails and cars attached thereto will move at double the ratio of speed of the axles, since the movable rails are carried along with the axles and also have a motion relatively to such axles, owing to the friction between the wheels and the movable rails. In the combination of platforms above referred to, the two outer ones are mounted on the axles and the middle ones on the peripheries of the wheels, with the result that the differential rate of speed between the three platforms is constantly maintained, no matter at what rate it is found desirable to run the train for the safe admission of passengers.

It is intended that these platforms and cars shall travel continuously on an endless railway and that passengers shall step upon the platforms, traveling at the lower speed, and thence to the cars provided with seats traveling at double the speed, while the railway is in motion.

In this connection it is supposed that a person can step on a platform that is approximately level with the ground and moves at about the rate of a walk, or say four miles per hour. In this city the drawbridges, when swinging on the abutments, move at the rate of from $3\frac{1}{2}$ to $4\frac{1}{2}$ miles per hour, and people do not hesitate to step on or off while the bridge is in motion. While 4 miles per hour is therefore generally accepted as the average gait of a walk, it has been assumed in this instance, that in practice, and to insure additional safety, the speed to be given to the outside platforms, or the axle speed, should not exceed 3 miles per hour, and that each succeeding platform should increase at that rate.

The diagram on sheet No. 3 of the patent specifications, explains the further application of the principle to platforms that are to travel at more than twice the axle speed, and in such case, as in the combination of three platforms, the speed of each succeeding platform is always maintained at an exact multiple of the axle speed. The certainty with which these differential, or multiple, speeds are maintained for each belt of moving platforms through motive power, at a low rate of speed, is applied to the axle only, is the advantage of this system, because by increasing or decreasing the axle speed all platform speeds are simultaneously and automatically increased or decreased, and the practical operation of the system is thereby made extremely simple and safe.

In the construction of the train of the three platform combination the two outside platforms, traveling at the lower speed, are supported upon a wooden framework, consisting of four longitudinal floor sills secured at their ends by transverse end sills; they are built in sections 9 feet, or more, in length, and each section is supported on a pair of wheels and one axle placed near one end. The other end of the section rests upon the rear of the preceding one and is coupled to the same. The weight of that end of the section, however, does not come upon the drawhead, but is taken up by two castings, one on each side, and these rest upon bearing plates on the end sill of the preceding car. The cars are therefore designed somewhat following the principle of two-wheel carts, having practically no rigid wheel base and are constructed to go round curves of small radius.

The wheels are pressed upon the axles to any required gauge, but the axles are considerably longer than the usual practice, and have outside bearings for the support of the outer platforms.

The middle platform, or car, which travels upon the top of the wheels, is built in sections of the same lengths as the outside platforms. A track of the same gauge as the fixed track, but consisting of two continuous flexible rails, is attached to the bottom of the middle platforms and holds them in position while traveling on the peripheries of the wheels. These rails are made flexible to assist in going round curves of varying radii, and this is accomplished by making them of three strips of steel (see detail drawings) set on edge and joined in such manner that each wheel has, at all times, a bearing on at least two of these strips which form the rail. They are joined by expansion bolts, like the rails in the fixed track, and

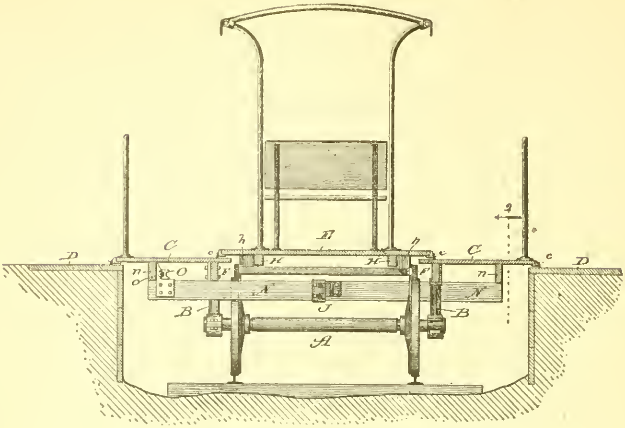

FIG. 1.—TRANSVERSE SECTION.

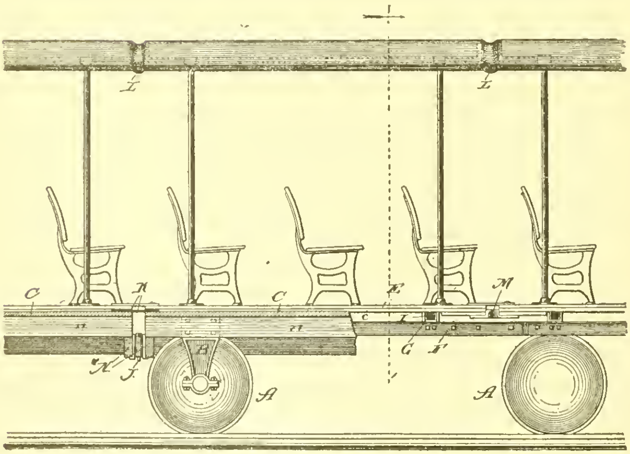

FIG. 2.—SIDE ELEVATION.

A, Axles; *B*, Journal Brackets; *C*, Platform; *D*, Stationary Platform; *E*, Car; *F*, Flexible Rail; *G*, Bracket; *H*, Sills; *I*, Rubber Spring; *J*, Coupling Pivot; *K*, Cover Plates; *L*, Flexible Covering; M, Spacers; *N*, Beam; *O*, Casting to slice on wear plates.

their ends are left a sufficient distance apart to provide for the necessary amount of longitudinal motion, expansion and contraction required when passing a curve. The rails are rigidly fastened at equal intervals to the cars by means of chairs, thus confining the longitudinal motion to short chords, and the rails, being thin and flexible and having no intermediate fastening through the pressure of the flanges of the wheels against them, conform to any curve which they may be called upon to pass. To run such a railway without flexible rails on an endless track is impossible. The rails might be curved to one curve only, in which event they would run on that curve but not on tangents or other curves, or they might be left rigid and straight, in which event they would be useful on tangents, but not on an endless track, which must necessarily have at least 360 degrees of curvature.

A rubber or steel spring is interposed at each chair between the flexible track and the platform to insure smooth riding, but, as the speed is low, not much rolling movement or noise need be expected, the motion of the cars being more like that of a sleigh.

The middle platform, or car, may be made as wide as desired, and with as many transverse or longitudinal seats as desired; it may be an open or a closed car, but should have a passage way on each side for the use of the passengers. Steadying posts, or railings, are placed within arms length of the edge of the platforms, to be used by passengers in getting on or off. Sliding plates are provided at the junction of the various sections, both of the cars and side platforms, which are bolted to one platform and lap over the other, so that they may slide freely in passing the curves. The steps from platform to platfrrm are not over two inches high, and have fastened to them a narrow apron of coarse rubber or leather, which effectively prevents anyone from being caught under the edge of a platform, or becoming in any way injured.

That it is safe and practicable for passengers to get on or off a platform moving 3 miles per hour, can be proven by fitting an ordinary flat railway car with overlap and post, or railing, as proposed, and give the matter an actual test in practice from a stationary platform. Railway men, as a rule, do not doubt that even old people can step on such platforms, provided they move slow enough and are not much above the level of the ground. There are, moreover, many ways by which this step can be made much safer than the boarding of a train or a street car in the crowded streets of a city. There will, of course, be attendants, and rubber mats may be placed along the edges of platforms to secure better footing. As there will be no vehicles to look out for, passengers can use their time and deliberation when stepping off and on, and the chances of getting injured from a fall on a board are trifling as compared with those incident to a fall on a street, where a person is in danger of being run over. People without their limbs are not supposed to travel on public conveyances without attendants, and there should be no difficulty in rolling invalid chairs on the platforms while in motion. In this connection, it is well known that railway speeds are often over estimated and that few people outside

of railway men have a correct conception of the low speed represented by three miles per hour. Derailments and the heating of journals or bearings, as well as breakages of couplings, bolts, or other parts of the rolling stock, occur much more frequently on trains running at high speed than at low speed; and when they do occur at low speed they are not followed by serious accidents. Breakages of locomotives in this case are avoided altogether, as the source of motive power will be stationary, and there can, therefore, be no question as to the safety of passengers while in transit.

The motive power will be transmitted by cable or electricity, with present conditions favoring electricity. If electricity is used it will be supplied through circuits from dynamos to motors attached to the axle of the platform, the number of motors depending upon the amount of horse power that each motor will develop. They will all be started and stopped simultaneously once a day from a central or intermediate station or stations, as may be desired.

As regards the power required to transport one passenger, the manifest object of the road is to combine immense carrying capacity with low speeds, hence, when there are no crowds to transport there will be no necessity for a road of this class, as the power required to transport one passenger would in that case probably be greater than on an ordinary railway. But, when the crowds are there and the railway attains its object, then the motive power required to transport one passenger will be much smaller and probably not exceed *one-fourth* of that required on an ordinary railway.

A considerable saving in operating expenses will result from the fact that no motive power is wasted by constant stops and starts, and that owing to the low speed the wear on the track and rolling stock will be slight.

NUMBER OF PLATFORMS.	NO. OF SEATED PASSENGERS CARRIED PR. HR.		
	Two Seats Abreast.	Three Seats Abreast.	Four Seats Abreast.
First platform moving 3 miles per hour, then second platform moving 6 miles per hour will carry	21,120	31,680	42,240
Third platform moving 9 miles per hour will carry	31,680	47,520	63,360
Fourth platform moving 12 miles per hour will carry	42,220	63,360	84,480
Fifth platform moving 15 miles per hour will carry	52,800	79,200	105,600
Sixth platform moving 18 miles per hour will carry	63,360	95,040	126,720

The system becomes, therefore, applicable wherever large crowds require transportation, as on main thoroughfares, like Broadway, New York, the Strand, London, or Rue Rivoli, Paris, or at bridges and tunnels joining large cities, or on exposition grounds, or for suburban traffic in general.

To make this point clearer, the following table gives the number of

passengers that can be carried, seated, per hour on a railway built on this plan, at the differential rate of three miles per hour, and with two, three and four seats abreast respectively, placed every three feet.

It will be seen with reference to this table that even the lowest figure, 21,120 passengers carried by the second two-seated platform at six miles per hour, is far in excess of the capacity of any other known mode of transportation. At the Brooklyn bridge the maximum carrying capacity by the trains of the compound cable and steam railway is about 14,000 passengers per hour, and that is only made possible by appropriating every square inch of floor space for standing room. The ever increasing traffic on this bridge and the problem of how to provide adequate means for the same, have recently led to the appointment of experts, who are considering means of relief for the terminals of the bridge. It is believed that this railway, with proper modifications to conform with the local conditions, will meet the requirements of this bridge to an exceptional degree.

To resume, the main advantages of a railway on this plan are that, being endless and always in motion, and with a carrying capacity of passengers practically unlimited, the proposed mode of transportation comes nearer conforming to the American idea of locomotion than anything known in the history of passenger transportation. All the delays that combine to worry the traveler on an ordinary street or suburban railway are removed on a railway built on this plan, which is equally well adapted to depressed as to elevated tracks, and may have a superstructure consisting of light bents and simple trusses. On this railway, with its train of cars constantly in motion, it is evident there will be no waiting, no delays at stations, no time lost in consulting time cards, no switching or obstructing of tracks, no crowds, no smoke, no collisions, no misplaced switches, no train orders to misunderstand, but seats will be provided for everybody, while nobody can get left or lost, try as he may. All these advantages can be obtained by the simple effort of learning how to step on a platform moving at less speed than a walk.

As regards the application of this novel railway to a World's Fair, and especially to the *Columbian Exposition* of 1893, it should be remembered that there are two serious problems which have confronted every exposition management in the past, namely:

First—How to provide adequate means for the transportation of visitors within the exposition grounds, and

Second—How to furnish means of rest for the many millions of weary sightseers.

It is clear that the railway just described will dispose of both these problems simultaneously, and in a most satisfactory manner to the management and the public.

Transportation and rest, on the scale as offered here, and practically free and without limit, as furnished by this railway, has never been within the reach of any previous exposition, and the invention should be utilized in its fullest scope and widest sense. Heretofore, transportation within exposition grounds has chiefly been confined to crowded cars on ordinary

railway trains, where perspiring people fought for standing room, and where a journey meant untold discomforts. Likewise the provisions for rest have been so insufficient that the fatigue, incident to finding a special object was often so great that all interest in the same would disappear before the object was found. As a rule, seats on exposition grounds have commanded exorbitant prices, and as to the restaurants it has generally been understood that their use was limited to the length of the repast. This railway removes these defects and materially assists the exposition in one of its greatest missions, namely, to facilitate the study and the comparison between the various parts and classes of the exhibit.

To fulfill its object in the widest sense at the exposition, the railway should be free to all visitors and admit passengers without fare or additional compensation. No embargo should be placed on this condition, and every visitor, upon entering the exposition, should be made to understand that in purchasing his ticket, with perhaps a coupon attached, he has paid for the privilege of riding on the railway whenever, and for whatever distance he chooses. The addition to the price of general admission that would be required would be trifling when compared with the comforts of the visitors, and much less than if fare were collected for every ride. By an arrangement like this, the platforms composing the railway could be placed on a level with the grounds, the railway would not have to be fenced in, or be encumbered by ticket offices and gates, but could be thrown open to all, enabling everybody to get on or off whenever or wherever he pleases, without waiting or crowding. It is believed that such a railway will be a wonder in itself, not only as illustrating the American idea of locomotion, but because of its extreme simplicity of construction; and, after once tried, there can be no doubt as to its frequent repetition and future application until something is invented that is superior and better.

In conclusion it should be stated that the plans have been examined by mechanical experts and railway men, who have pronounced them *entirely feasible*. The theoretical and mechanical principles involved have been found correct, the arrangement for obtaining the increased speed of the central platform has been pronounced ingenious and the simplest and most direct method by which such change of speed can be accomplished, and the hope has been expressed that a road on this plan would soon be built and the important principles involved therein tested in practice.

DISCUSSION.

MR. RICHARD P. MORGAN:—In regard to statement that 63,360 people per hour can be carried, what length of track does that mean?

MR. M. E. SCHMIDT:—The length of track in this case is not necessary to give, because it will be in a circuit and the calculations are made under the assumption that no person will ride around the circuit more than

once. If it were three miles, for instance, the seating capacity is just the same. It means that so many seats can pass a given point, to accommodate people to get on.

MR. MORGAN:—You assume that it is loaded to its full capacity?

MR. SCHMIDT:—Yes.

MR. MORGAN:—Do I understand that there are two six-mile platforms assumed in those last figures to have seats on them?

MR. SCHMIDT:—In the last figures the nine-mile platform is the only one that is supposed to be seated. If, for instance, a fourth and a fifth platform were added with four seats abreast on the latter it will reach the enormous figure of 105,600 people per hour.

MR. E. L. CORTHELL:—How do you take care of your grade crossings, streets, etc?

MR. SCHMIDT:—In a crowded city it would not be practicable to run this railway on the level ground. It would have to be on an elevated or underground track. We built this model to show the exposition people what we can do. We have built the cars, which are shown here, open, as they should be during the exposition and in the summer time. If this system becomes applicable to suburban traffic, and for rapid transit generally, the cars would have be boxed up like ordinary passenger cars, and then the track would have to be elevated or be placed under ground.

MR. CORTHELL:—Along an elevated road, would not one of your essential principles be eliminated? The object of this is that people can get on or off at any point; how do you get them on or off on such an elevated structure?

MR. SCHMIDT:—We would in that case have a narrow strip of continuous walk next to the slowest moving platform, and the stations would be very inexpensive structures and at frequent intervals. There would not be any waiting rooms, because people would not have to wait. Once in each block an ordinary staircase for people to ascend and a gate to pass through and deposit fare would be all that is required, and people would then be ready to take their seats. The estimates we have, made by a member of the Society, state that the elevated structure would cost probably a trifle more than one-half of what an ordinary elevated structure costs which carries locomotives. We have no need of locomotives, and the structure would be lighter and cheaper.

MR. BENEZETTE WILLIAMS:—In the case of the Brooklyn bridge, would not the application of a similar principle to the platform at the extremities with one simple movable platform and one movable platform for the cars be better than two movable platforms making the whole circuit of the bridge?

MR. SCHMIDT:—Yes, it probably would, and as the paper stated in the case of the Brooklyn bridge, there are likely to be modifications of the plan.

This model, as already stated, was made for the exposition and shows two outside platforms, as it will probably be necessary to admit people from both sides. For any ordinary use and suburban transit there would

be no necessity of having two outside platforms, as shown here, but in place of that we would probably want a third platform going nine miles an hour. At the Brooklyn bridge we would not want two outside platforms, unless the people that get on on one side are obliged to get off at the other, and unless it was found better to get them all on on one side and off on the other, then it might be best to have the two outside platforms.

The radius of the curves on this model is 108 feet, which could be reduced under the construction we have adopted for the cars. You will note they have one pair of trucks and no rigid wheel base. The total curvature is very great, being 458° in the 1044 feet of track, which this model represents.

Mr. O. Chanute:—Is it proposed at the exposition to put that railway in the grounds or within the buildings containing the exposition?

Mr. Schmidt:—That question has been brought up by some of the gentlemen in charge of the exposition and has not yet been settled. There will probably be an open air belt railway going from building to building, and then others of smaller scale in the large buildings, like Machinery Hall, to take people from place to place and exhibit to exhibit within the hall.

Mr. Chanute:—In that event, would it not have to be located so as not to interrupt the circulation?

Mr. Schmidt:—It would have to be located so that people could get across, by leaving out occasionally several of the seats, or provide ornamental foot bridges. In the buildings it could be placed on galleries, where it would prove a great attraction. Only half of the car body requires to be bridged over, and that would not require a very great elevation; say about 7½ feet.

Mr. Silsbee:—In the buildings on a gallery, or raised up from floor it would give a fine view of the interior of the building.

Mr. J. F. Wallace:—In regard to grade crossings, I do not know whether you have kept in mind the fact that there will be a large number of railroad tracks all through the exposition grounds to bring in exhibits, and whether this would not interfere with them.

Mr. Schmidt:—I have taken care to show that we can use grades of 320 feet to the mile and much steeper ones. We can, therefore, always go underground whenever a crossing of that kind would be required, or else go over it on a bridge. The system admits of very steep grades, over which the cars will go without any possible way out of it, after the railway is once set in motion.

A Member:—I think it would be of interest to know what your estimate is,—what you think would be the length required for this exposition?

Mr. Schmidt:—For Jackson Park we have figured on a circuit of about three miles. Our estimates have been based on that length. The rolling stock is, of course, the most expensive part of the railway, but on a temporary road, as at the exposition, the rolling stock would not have to

be very costly and would still answer all purposes. We estimate that about $10 to $15 per foot would be the price of the rolling stock.

MR. O. E. WINGER: -You do not figure into that the cost of your plant for moving it.

MR. SCHMIDT:—No, that is not figured in, simply the rolling stock with which to equip the road.

MR. WINGER:—You have, in fact, made an estimate on three miles, plant and all; in round numbers, what is it?

MR. SCHMIDT:—About $500,000, which includes the expenses of running it during the exposition. Of course, the details of the estimate I do not feel at liberty to give—I can only state the sum in round numbers. The weight of the railway, three miles, loaded with passengers, has been figured at 2,400 tons, and the power required to move this load has been estimated. It will be supplied by electric motors, say, of fifty horse power each, attached at equi-distant parts in the circuit to the axles. The motors are connected by wire with a central station, from which the train is started and stopped simultaneously.

MR. CHANUTE:—What is the correct horse power?

MR. SCHMIDT:—Twelve hundred horse power, or rather between eleven and twelve hundred. Some of the experts figure it below 1,000, but we have assumed the larger number.

On the request of a member the model was set in motion.

MR. SCHMIDT:—This model is run by a quarter horse power motor, moving an endless chain which pushes ahead the cars. We only apply the power at one point, however. A little more electricity will make it run faster.

MR. CHANUTE:—Do you take into consideration the amount of curvature we have?

MR. SCHMIDT:—The central platform seemingly goes faster than twice the speed of the outer two. That has been generally remarked by people who have come to look at this model. In reality we find by applying a simple test of laying on three coins, that the central platform remains behind about 10 feet in 1,000, which is due to the slip on the curves. I presume when the cars are loaded with passengers the multiple will be attained almost precisely.

In making this model every dimension has been reduced thirty-six times, but when it came to reducing some of the smaller measures it was impossible to make everything to scale. For instance, this step from the stationary platform onto the first moving platform is not more than two inches, and from the first moving platform to the more rapidly moving platform there is the same difference. In this model this step seems much higher.

MR. WALLACE:—But in regard to crossings, you know to the large buildings; machinery buildings particularly, there will be railroad tracks laid, and there must necessarily be a great deal of communication between the different parts of the exposition grounds.

MR. SCHMIDT:—During the construction of the buildings and the lay-

ing out of the grounds, we would probably leave gaps in the road until everything is ready.

Mr. Wallace:—In the machinery hall you will have to bring in daily supplies of coal and fuel and supplies of every kind.

Mr. Schmidt:—We can carry those at night.

Mr. Wallace:—You will have a great many places that will need supplies that would have to be brought in.

Mr. Schmidt:—We think this railroad will carry a great deal of freight in the beginning, getting the exhibit ready.

Mr. Wallace:—On the Jackson Park site there will be an inlet from the lake, I understand, where people can land from the vessels.

Mr. Schmidt:—We can very easily go over a bridge.

Mr. Wallace:—One reason I asked that question was this: When you come to put it in practice, won't you find it necessary to either elevate or depress?

Mr. Schmidt:—That depends on the locality. If the railway is to be free to everybody, so that no additional fare will have to be collected, then it would be best right on the ground. We will be prepared, however, to avoid obstacles, or the obstacles must avoid us, whichever is most important of the two. One of the gentlemen, connected with the construction department of the fair, saw great possibilities for the landscape gardener and varieties of ways of bringing out features of the ground by the presence of a railway of this kind, knowing that we can go over grades, as shown in this model.

Mr. Wallace:—What is the height of the car above the ground?

Mr. Schmidt:—Seven and one-half feet. The wheels are below ground and only the body of the car is above the ground. The cars can be depressed still further by sinking them down more and getting them practically level with the ground, if that is thought desirable. On the other hand, if it is found desirable to fence the road in and leave gates for the passage of people, that would be an easy matter to accomplish.

Mr. Williams:—In case of the breakage of a wheel or coupling, or any portion of the apparatus——

Mr. Schmidt:—We are running at such a low rate of speed that derailments are not likely to occur, and if they do occur the consequences cannot by very serious. On the contrary, as the speed is so low, the railway will stop at once should any obstacle find its way onto the track.

Mr. Williams:—What I had in mind was the whole derangement of the traffic of the road; everything would come to a stand still along the whole length of the circuit until the repairs were made.

Mr. Schmidt:—That, of course, you would have to expect of any kind of conveyance; if anything gets out of order it will have to be repaired, and while the repairs last it will have be stopped.

Mr. Williams:—On individual trains it only deranges one train, as a rule.

Mr. Schmidt:—Our speeds are against any serious results in that line. If we were running at very high speed it would be likely to cause trouble.

When anything breaks on the machinery of a cable way, the wholerail system stops.

MR. WINGER:—You have a train of three miles, would not considerable damage occur before such a long train could be stopped?

MR. SCHMIDT:—I think the very length of the train is a criterion against that supposition. The train will stop short, because of its continuity and the fact that it occupies a closed circuit on the track. When you come to consider this train—suppose you part it at one place and put an engine in front, you have the entire train to pull, whereas, if you connect, or close the belt and put the motors in, each motor pushes the train as well as pulls it. In that way the motive power is so well distributed that if anything should happen, at the low rate of three miles an hour, it will certainly result in stopping the whole train without any serious damage.

MR. WILLIAMS:—How would you stop the power simultaneously throughout the whole?

MR. SCHMIDT:—By a switch operated at the central station. The motors are to be attached, say, to every thirtieth car, and a circuit is laid connecting them all with the central station. Moreover, small observation towers may be put in where an observer can operate a switch which stops and starts the train by disconnecting the circuit.

MR. WINGER:—Do you think the traction of one pair of wheels would be sufficient to move thirty or forty cars?

MR. SCHMIDT:—Yes, because the motors are quite heavy. But if not heavy enough the traction can still be increased by adding to the weight of the trucks that carry the motors.

MR. WINGER:—If it would be necessary to distribute the motors, could you not have more motors with less power?

MR. SCHMIDT:—Yes, have twenty-five horse power and apply them more frequently.

CONSTRUCTION AND OPERATION OF CABLE AND ELECTRIC RAILWAYS.

BY H. M. KEBBY, C. E., MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read December 17th, 1890.]

We have frequently been informed during the past year that electricity would supersede cables as a motive power for street railways. This does not seem to be the case as to the principal cities of the country. New York, Chicago, Washington, San Francisco, Baltimore and Cleveland are still building cable roads. Location and amount of business will of course have a good deal to do with the decision of the directors of street railway

companies in this matter. As a matter of fact, the great mileage of electric roads being constructed is confined, with hardly an exception, to lines upon which the traffic would not warrant the construction of a cable road. With a certain amount of traffic, no power is cheaper than animal. This traffic, increased, reaches a point when steam dummies, if permitted, come next in order, then electric and then cable power. With a volume of traffic equal to that of the Chicago City Railway, the total cost of operating by cable is only one-third of what it would be with horse power. Certain expenses involved in the operation of cable railways are largely independent of the amount of traffic carried. It costs a certain sum to run the naked cable. The larger the number of cars propelled by this cable, the less the cost per car mile. With electricity the cost is far more nearly in proportion to the volume of traffic. We frequently meet with the statement that 40, 50 or 60 per cent. of the power used in the operation of a cable railway is consumed in operating the cable alone. These statements are very misleading to the general public; as you will see, without argument, that it means nothing. If you have no cars running all the power (100 per cent.) is used to propel the cable. As you increase the number of cars this proportion is largely reduced, until, if you are operating a ten-mile cable with the number of cars assumed in this paper, only about 48 per cent. is used. Only one-sixth of the cost of operating the cable railway increases directly as the number of cars. One of the principal arguments used by electricians has been that the cost of installment of an electric road was a great deal less than for a cable road. I believe that, so far, they have had this part of the argument pretty much to themselves, but I will endeavor to show by the figures that when comparing the same class of construction, the difference is small. Of course if you take a third-class electric construction and compare it with a first-class cable construction, it will show to the disadvantage of the cable road, but this is not comparing like with like. I believe the following figures are derived from the most reliable sources. For the purpose of comparison, I will take a road of ten miles of single track and running 30 trains. First, taking the question of rail, which, if the amount of weight carried is considered, would call for a heavier rail on an electric road than on a cable road, as the motor cars will weigh on an average 6,000 pounds more than a grip car. But as in these days of permanent structures, the 78 pound section of rail is the most generally used, we will call the rails the same.

The paving for an electric road will reach from rail to rail, but in a cable road we must deduct the area of the slot rails and manhole covers, which is $36^{42}/_{100}$ squares per mile. This, at \$26, is \$946.42 per mile, or for 10 miles, \$9,464.20. The yokes for a cable road cost \$5.30, and 1,320 yokes will be per mile, \$6,996. To make as good and durable construction for the electric it will require steel ties. These will cost with steel chairs \$1.30, 1,320 ties per mile will be \$1,716.00. This shows a gain for the ten miles of \$52,800, in favor of the electric road. The concrete will cost \$40,000 more for the cable road than for the electric road. The

excavation will cost $1,226 more per mile, or $12,260 for ten miles on the cable than on the electric road. Carrying sheaves and manhole frames and covers will cost the cable road $13,600.00. Slot rails will cost for ten miles $49,280.00. Paving plates for cable road, where they are used, which is not the fact in all cases, will cost $26,400.00. Sewerage for cable roads, $2,500.00. Bolts extra for cable road, $1,500.00. Large sheaves and pits, $9,000.00. Extra labor on cable road, $20,000.00. Cables, $15,840.00. Grips, $2,400.00.

Wiring and poles for electric road, $52,500.00. Motors and trucks, $126,000. Machinery in power house of electric road will cost $70,000. Machinery in power house of cable road will cost $45,000, showing a difference in favor of cable road of $25,000.

Then in tabulated form we have:

DIFFERENCE IN FAVOR OF CABLE ROAD.

Paving	$ 9,464
Wiring and poles	52,500
Motors and trucks	126,000
Machinery in power plant	25,000
	$212,964

DIFFERENCE IN FAVOR OF ELECTRIC ROAD.

Yokes	$ 52,800
Concrete	40,000
Excavation	12,260
Carrying sheaves and manholes	13,600
Slot rails	49,280
Paving plates	26,400
Sewerage	2,500
Extra bolts	1,500
Large sheaves and pits	9,000
Cable	15,840
Extra labor	20,000
Grips	2,400
	$245,580

Showing a difference of only $3,261 per mile in favor of the electric road.

These figures have all been derived from roads built during the present year, excepting the item of ties, which, if of oak with proper steel chairs, will cost as much as the figure for the steel ties. It is necessary, in order to compare the two, that there should be as good a support under the rail in one case as the other.

One very fallacious claim made by the electricians is that the cable road is laboring under a disadvantage in having to keep a dead weight moving all the time, namely, the cable, sheaves and winding machinery. Now the weight of a ten-mile cable is 132,000 pounds, carried on sheaves with the best lubricated journals that can be devised by mechanical engi-

neers for the purpose. The electric roads are carrying, on the other hand, an excess of 6,000 pounds for each one of their motor cars, which for 30 motors is 180,000 pounds. This, too, has not the advantage of being carried on well-lubricated sheaves like the cable, but must be rolled along on a rail which is always covered more or less with dirt and mud from the street.

I will now give you a few figures on the cost of operating the two systems. Operating expenses for cable roads we are positive about. For electric roads they are extremely hard to obtain, but from what I have been able to learn the result is here given. For a cable road 10 miles long and operating 30 trains, the figures include

Power house expenses, per car mile ....
Grip repairs and renewals, per car mile..................
Grip repairers' wages, per car mile......................
Lubricants for carrying sheaves..........................
Renewals for sheaves and every item of expense on road bed of every description,.............................
Renewals of cable..
Total per car mile......................... c. 2.441

This road has a curvature of 467 degrees, 30 minutes and 20,000 feet of grades of from 1 to 3.6 per cent.

The carrying sheaves for this line are lined with babbitt. This is not considered to be any advantage to the cable, but is done to make it run perfectly noiseless. Were these sheaves of chilled cast-iron, as is almost the invariable custom, it would reduce this item about .6 of a cent per car mile.

For the operating expenses of the electric road, I quote from an address delivered by Mr. George W. Mansfield, a director of the Attleboro electric road, and manager of the Thomson-Houston Electric Co., before the Street Railway Convention at Buffalo, last October:

"In a general way it has been my experience that the cost of operating an electric car per mile, and the mileage being in the neighborhood of 110 miles and under average conditions, perhaps grades of 5 per cent., I think that in a good many cases, under these conditions, counting simply the maintenance expenses, meaning the oilers, wipers or cleaners, grease, repairs to all of the electric apparatus on the cars including the truck, and not including any fixed charges or anything of that kind at all, the cost of operation can be reduced to the neighborhood, on large roads, of about 3 cents per car mile. On small roads it costs more; perhaps 4 or 4½ cents."

Mr. Mansfield's estimate, from my observation, is a very low one. To this must be added the power house expenses, which from Mr. Crosby, an electrical engineers' figures, are

For an average of four electric roads....................	3.067
For repairing electrical apparatus as above...............	3.000
Total per car mile...........................	6.067

From indicator diagrams taken all day long and for several days with different kinds of weather, we find that the power required to move the cables and machinery was 139.95 horse power, and the average when pulling cars and passengers was 287 horse power or $47^{65}/_{100}$ per cent. of power for cable and machinery.

From what I can learn of the loss on an electric road, it would be, under average conditions, 58 to 70 per cent., and more in bad weather.

I should like to quote here from a report prepared and read before the last annual convention of the American Street Railway Association, by Mr. Allen, president of the Davenport Electric Road, a member of that body, who was appointed a committee for that purpose:

"Nearly everyone of the street railway men present will uphold the statement that the only problem before us, and the one about which we are always anxious is, 'What can we do to keep our motors out of the repair shop?' We don't worry about our station or our overhead wires; we scarcely have time to think about them; we are constantly at work upon and perpetually annoyed by our motors; a lame armature, a burnt field magnet, a broken gear—these are our every-day trials.

"The electrical parts of the motor in which we are most interested are the armature, field magnets, and the controlling switch, or rheostat. The armature of an electric motor is its wonderful and interesting, as well as its most expensive and troublesome part. A street car is the most overloaded vehicle known to mankind. It may run a week with a light load and then suddenly receive enough passengers to load fairly well three or four ordinary cars; the motorneer may forget to oil either the car or motor; he may reverse motor accidentally or purposely to avoid an accident; these and many other causes require of an armature more work than it is capable of; hence, a burn-out. On the other hand, the armature itself may be at fault; an armature such as we use to-day consists of a shaft surrounded by a metallic core. Around this core is wound the best insulated wire, each coil terminating at the same end of the armature and being attached there by means of solder or screws to the bars of the commutator. The shaft of the armature will in a few years become worn by its bearings, and it would be well to have bushings or sleeves placed around the shaft at those points, such as the Thomson-Houston Company use, which sleeves can be removed. As there is no wear to the core, and as the commutator can be renewed when worn down, which ought not to occur in less than two or three years, an armature should then have as long a life as one could desire, were it not for the coils of wire. Where these coils cross around the head of the armature they chafe on each other and destroy their insulation. Where they end in the commutator they loosen. By an excessive load or careless driver they burn out. It may be possible to repair the armature by rewinding one coil or by refastening the loose ends, and even when a deep coil is burnt the total rewinding with new wire should not cost but forty or fifty dollars. Could we but prepare for the burn-outs by having the car on some side-track near the repair shop where it would not interfere with our running time or cause a hindering

of cars, we would not feel so aggravated, but it happens invariably at the time we need the car most urgently. We can watch our gear and bearings, and when worn they may be replaced at convenience or at night, but an armature gives out without warning. It is on this account that those systems advocating but one motor to a car must give us positive assurance of no burn-outs, for were it not for the double motor, now so generally in use, we would see crippled cars being towed into the shop, greatly to our discomfiture. In the matter of minor details, such as cables, terminals, trolleys and gearing, the electric manufacturers have made the greatest improvements in the past eighteen months, but so far as we can obtain information, based on actual facts, there has been but little improvement in the armatures. The Edison Company has recently announced a new armature, but we have been unable to learn what results it may show.

"The switch-box, such as used by the Sprague-Edison and Westinghouse, is an apparatus that, if given proper care so as to keep the brass plates and buttons smooth, ought not to cause much trouble. It is arranged so as to distribute the current through different parts of the magnets or the motor, according to the degree of speed or work required. It is somewhat in the way of passengers when the platform is overcrowded. The rheostat used by the Thomson-Houston Company is out of the way, being underneath the platform; although it is burnt out occasionally and damaged by rain leaking through the platform, these defects should be easily overcome. It is claimed that, owing to the use of the rheostat of the Thomson-Houston Company and the resistance coils as used by the Westinghouse Company, that the cars start much more easily and without jerking, and that the motor is less liable to burn out, as they avoid throwing in an excess of current. The first claim is true, but we cannot find evidence to support the latter claim. On the other hand, it has been claimed that motors using a rheostat require on an average run from fifteen to twenty per cent. more power than the Sprague-Edison motor. It does not necessarily follow that this is due to the rheostat; it seems likely that it is due as much to a difference in the winding of armature or fields. It would be most desirable, therefore, to ascertain from our various members the actual number of burn-outs of fields and armatures of both varieties of motors and at the same time the average power used per car. This cannot be obtained by writing for reports, as many roads do not keep an exact record, or will not report the same. The grades of roads must be considered, the car mileage, and loads carried; also the system or manner with which motors are repaired and cared for."

Summing up, therefore, if our premises are correct, as we believe them to be, if a street railway company were considering the proposition of motive power for a line 5 miles long of double track in a metropolitan city and had the means to build a strictly first-class road, if they decided to put in the cable, they would have to invest $32,616 more than for an electric road. This sum capitalized at 5 per cent. would require additional

earnings of $1,630.80 per annum, but we are satisfied that if the business of the road will warrant thirty trains per diem, averaging, say, 100 miles daily of two cars equaling 6,000 car miles per diem or 2,190,000 car miles per annum, this would cost on the cable $53,457.90: on the electric road with the same mileage it would cost $132,867.30. This shows a difference in favor of the cable of $78,409.40, from which must be deducted the extra interest charge of $1,630.80, leaving net balance of $76,778.60. You will notice that we figure only on cost of motive power and expenses incidental to the two systems. The question of general expenses, wages of grip or motor men and conductors do not enter into the problem in considering their relative merits, as these items would not differ materially for the two systems. We are perfectly well aware that electric roads are being almost daily constructed, costing much less money, but upon the other hand cheap cable roads have also been built; one I have in mind cost only $25,000 per mile and has done for five years past, and is still doing, good service.

DISCUSSION.

MR. E. D. MEIER:—I have been much interested by the paper just read, but cannot fully agree with its conclusions. I have always considered the cable system as unmechanical, and believe that its inception and invention was never due to an engineer or to a mechanic. To take a moving body weighing some 30 tons, and moving at a regular speed of 8, 10, or even 15 miles an hour, and attempt to attach to it a body weighing two or three tons which is standing entirely at rest, without some means for *gradually* bringing the speed of the latter body up to the speed of the moving body is unmechanical, and, in my judgment, bad engineering. In point of fact the matter is managed in two ways. Either the grip is gradually closed, allowing the cable to pass through the jaws, tearing, grinding, and crunching both the cable and the grip shoes, or reliance is placed on the slack of the cable, which is purposely increased, so that as the grip closes upon it the surge in the tightening cable is taken advantage of to break the force of the sudden pull. In the earlier cable patents, of which I have looked through hundreds, there were a number of devices, such as long springs, or even dash-pots intended to break the force of the blow. But these seem all to have been abandoned as too complicated, and the cruder devices just mentioned have come into general use. It is evident that under such usage the cable must be rapidly destroyed, and there is the principal item of cost in the motive power of cable roads.

It is easy to be seen that the amount of shafting, belting, etc., necessary in an electric railway power station must cost more to keep up than the simple though ponderous machinery in a cable power station. But a well-managed electrical road will not cost as much for the total repair account as cable roads with the tremendous expenses of the new cables.

The question of curves and grades and a great many other circumstances will always influence the choice of an engineer in regard to system to be chosen. Each road really presents its own problem. As the electric road is compelled to run heavier cars, its track should, if anything, be built better and stronger than that of the cable railway. I hold that both should follow the best practice of steam railways in this regard. In first cost the tremendous expense of excavating, yokes, concrete, drainage, etc., will generally make the cable by far the most expensive construction. The total cost per mile of the electric road will depend very largely on the number of cars to be run. This question would influence the amount to be charged per day for interest for investment. This I have, therefore, left out of the calculation, confining myself to the actual cost of the power, including in same all labor in the power station and for actual care or repair of the line, the motors, etc., and, in general, all fuel, oil, grease, tar, waste, water and repairs justly coming under the head of the cost of power. As at least one of the gentlemen from whom I have received data was unwilling to have the name of his road mentioned, I give my table simply under the head of "Cable, Electric I, and Electric II." I will further state that Cable and Electric II have the same kind and make of Corliss engines, and the same boilers. Electric I, on the other hand, is a high-speed engine station. Cable and Electric II have much the same grades to overcome, except that Electric II has more of them. Electric I has but one long grade, but on the other hand runs through poorer streets, and suffers more wear and tear from the prevalence of dust. I obtained the exact life of the first cable on the cable road, and assumed for the balance of the time that the life of the new cable would be double that of the first one, which was certainly a fair assumption, and from the two deduced the cost to be charged for this item of expense for the number of days compared. The number chosen, 198, was the most convenient because it fitted with the division of time in the statistic reports of road Electric II, and being somewhat over six months I considered it long enough for a fair comparison. While it is possible that improvements in the cable itself may somewhat increase its life, and therefore reduce the cost of repair per day, in the case of electric roads the repairs on motors and motor trucks will be very much more reduced, since the companies are beginning to put in their own machine shops. They will therefore pay about one-third for their supplies, the other two-thirds being now consumed by the cost of talent in electric experts, which will in the future be unnecessary. I therefore believe that the table I herewith present is conservative. While it may be urged that in the cable road the train is always composed of two cars, while in Electric II at least for somewhat over one-third of the time each day the train consists only of the motor car, and Electric I always runs two cars per train, it would not be fair to deduce from that, that the cost per car mile, instead of per train mile, would show very much more favorable results for the cable. For the reason the electric road runs with its motor only at times, is because the motor car is a very comfortable car, and in fact the one preferred by the

passengers, while the grip car on a cable road is available only in good weather. On the other hand, the addition of a trail car does not mean double the power required to haul the train, since I have found it to add only from 1.9 to 3 horse-power to the average power required per motor car.

In the case of the cable road the power required per train varied during the day from 12.86 h-p to 17.61 h-p. In Electric II, the power at the engines per car hauled varied from 6.87 h-p to 11.85, so that the amount of power per car is less for the electric road than for the cable road.

Furthermore, the point which interests the manager of the street railway line, and which must influence the choice of power, is the cost per passenger carried and the cost per passenger mile. This, will be seen, decreases very rapidly in the case of the electric road, as the number of passengers increases, and in the comparison between Cable and Electric II, is all in favor of the latter.

The reason Electric I shows higher results on these two items lies in several conditions. First, the much smaller number of passengers; second the condition of the streets being much worse than for the other two roads compared: third, the use of high-speed engines in place of more economical types. This not only affects the fuel, oil and water bills, but also increases electric repairs, since the danger of racing is greater. In

COMPARISON OF COST OF POWER ON CABLE AND ELECTRIC RAILWAYS, 1890.

	CABLE.	ELECTRIC I.	ELEC. II.
Length of road—round trip, miles	9.64	9.00	12.22
Number of days compared	198	198	198
Cost of power, including labor, fuel, oil, grease, tar, waste, water, and repairs	$29957.72	$23604.96	$26687.88
Number of regular trains per day—mean	20	11	25
Total number of round trips	61380	58014	82630
Mean number of round trips per day	310	293	417.3
Total number of train miles	591703	522126	98079.5
Total number of passengers carried	2928918	1608[illegible]32	3032425
Time per round trip—total, minutes	72	82.5	96
Stops at terminals, minutes	8	10.5	19
Actual running time per round trip, minutes	64	72	77
Running speed—mean—miles per hour	9.038	7.5	9.522
Cost per round trip—cents	48.8 cts.	40.8 cts.	32.3 cts.
Cost of power per train mile	5.06 cts.	4.53 cts.	2.72 cts.
Cost of power per passenger carried	1.023 cts.	1.38 cts.	0.88 cts.
Allowing each passenger ¼ round trip: cost per passenger per mile	0.424 cts.	0.61 cts.	0.29 cts.

the case of cable roads, the dead weight of the cable which has always to be pulled tends to equalize or at least to ease off the otherwise very sudden fluctuations in power requirements. In the case of the electric road with Corliss engines, the long lines of shaft, and many heavy pulleys with their momentum perform this office. And I have found that the larger the number of cars, and the larger the amount of machinery necessary in the power station, the less the range of this fluctuation of power, and therefore the greater the saving in electric repairs.

Mr. H. M. Kebby:—As to the cable road being unmechanical, that is simply an opinion. We could just as well say the friction clutch was unmechanical; it starts bodies of machinery from a state of rest to the speed of the the other part of the shaft by friction alone. The inventor, Mr. Hallidie, was considered by a great number of people to be a very bright engineer and mechanic. It was said of him, not long ago, by the brightest paper published in this country on street railway matters, that he is entitled to take rank as a local and public benefactor. The matter of starting the car and bringing it up to the same speed as the cable is, of course, not as easy on the cable as we would wish to have it, but as all roller grips, except those in use on the Brooklyn bridge, have been abandoned, it looks as though no device had been invented which would give as good satisfaction as the ones in use. The main principle to keep in view in any device which unskilled labor has to handle is simplicity; the more simple it is the less the repair bill. Any road situated as the Brooklyn bridge is could, of course, use a grip that will start the car and be as easy on the cable as one could wish. The "tearing, grinding and crunching" which Mr. Meier speaks of is something entirely foreign to my ten years' experience of cable roads, but we find, as a matter of fact, that the greater part of cable roads being built to-day are putting in grips which have no rollers on them, and roads which had rollers on their grips when they were started have taken the rollers off, as they considered they were useless. These roads are in St. Louis, Kansas City and San Francisco. The device in connection with the grip hangers to take the shock when the grip is first applied is still in use on nearly all roads, and there is not, nor ever was, anything more complicated about it than an ordinary every-day coil spring. As to the repairs on cable roads being more than on electric roads, we have the figures of Mr. Crosby and Mr. Mansfield, both of whom are electrical experts, which show that such is not the fact. The expense of excavating, yokes, concrete, drainage, etc., is, I think, overcome, as my figures will show by the cost of copper, poles, motors, etc., on an electric road, and the point to which electricians are now bending their energies would tend to show that they will use the conduit for their conductors as soon as they can stop the loss of current by proper insulation, a thing they have not yet been able to do. It seems to me that the $^2/_3$ on the cost of repairs which Mr. Meier proposes to abolish for the electric railway companies, is rather an exaggerated statement of what they pay for talent, and I think that the company which tries to run their road with any less talent than they do at present will pay a good deal more for repairs than they do now. As to the motor car being more comfortable than the grip car, that may be so in the winter but it is not so in the summer, and we have several cable roads in this country which run closed grip cars; we also have an electric road in St. Louis which is using a fac-simile of the open grip car for motor cars. Now about the power required at the engine to move a train. I have indicator cards taken all day long on three cable roads in St. Louis which show that the average horse power required to move a train of two cars is for No. 1—9.2, No. 2—10.6, No. 3—9.7. The one designated as No. 2 pulled a third car for $^1/_4$ of

every other trip. On an electric road in this town, I have been told by a gentleman that was present when the indicator cards were taken, that they showed over 900 h. p.; this divided by the number of motors running, there were no trail cars, and the superintendent said there were 51 motors, showed nearly 18 h. p. for motor alone. According to the statistics for the last quarter, published here, the road of which Mr. Meier's electric 11 is a part, two-fifths of its cars being run by horses, carried 1,997,747 passengers and made 117,330 trips. The cable line of his article carried 1,330-172 passengers and made 51,520 trips, and the third car pulled for ¼ of every other trip belonged to a line which carried 301,093 passengers in 33,672 trips. Now, as to efficiency and reliability of the two systems, the storms so general in the East during a part of December showed which were the most to be desired in bad weather. Associated Press dispatches stated that the electric lines had stopped running cars in Boston, Pittsburgh, Cincinnati, Springfield, Mass., Elmira, Scranton, and other places affected by the storm. The Boston dispatch read: "Electric cars are perfectly useless and the only way to get down town is to walk or hire a sleigh." The Pittsburgh dispatch read: "All street car traffic suspended except on cable roads." This was the second time within three weeks that this had happened in Pittsburgh, and some of the other towns mentioned above. During the blizzard in New York, several years ago, the cable line on 125th street was the only road in the city able to run cars; even the elevated roads had to stop.

MR. WINTHROP BARTLETT:—As to the cost of construction Mr. Kebby is entirely correct. It is not intended to compare the average electric road of to-day with the present cable roads. I do not know of a single instance where the permanent way of an electric road is as substantially and durably built as that of the average cable road. Usually the idea of the railway management is to replace animal power with the least expense, hence the money goes into the steam and electric plants and new cars, while the old permanent way is made to serve.

The large increase in mileage of electric roads during the past two years I believe is due to the low first cost, the flexibility, the adaptability to existing lines, and the anticipated economy in operating expenses. The first cost of an electric road is largely under the control of the stockholders. It can be built cheaply and at the same time be made to render a fair service for a short time, but the cheaper the first cost the higher the operating expense.

In October, 1888, during a visit to Richmond, Virginia, I was much pleased and surprised at the wonderful efficiency of the now noted electric road of that place. There were 25 to 30 16-ft. cars being operated on 11.8 miles of hills and curves with three small engines, which could not have possibly moved the empty cables necessary to operate the same line. The apparent ease with which these cars surmounted the heavy grades and rounded the sharp curves with heavy loads was certainly wonderful, and sufficient to convert the strongest advocate of the cable.

The history of this road teaches two things: First, that it is possible to

operate the ordinary street railroad with electric motors; second, that a cheaply built road where everything is taxed beyond the maximum capacity is a thing short-lived and disastrous financially. Instead of being efficient. as I first supposed, it has long since proved to be woefully inefficient.

The cost of construction of the electric road is in direct proportion to the number of cars operated, or to the business handled. I believe, that for a five mile double track road, suitable for either cable or electricity, that a business of 12,000 people per day of twenty hours is beyond the economical limit of the electric, and just at the beginning of that limit for the cable. Beyond this limit the first cost of an electric road, properly equipped, will not fall far short of that of the cable.

There is not so much doubt about the cost of construction as about the cost of operation. To arrive at an equitable comparison of the cost of motive power by cable and electricity all the items to make up this expense should be included. For the cable these items should be:

1. Wages of engineers, firemen, coal passers, laborers.
2. Fuel.
3. Water supply.
4. Lubricants, waste, etc.
5. Machinery repairs.
6. Building repairs.
7. Insurance and taxes on power house and machinery.
8. Cable renewals.
9. Cable attendance.
10. Cable lubricants.
11. Pulley expense, including renewals, lubricants, wages, etc.
12. Grip repairs.

For the electric road:

1. Wages of engineers, firemen, coal passers, laborers.
2. Fuel.
3. Water supply.
4. Lubricants, waste, etc.
5. Machinery repairs.
6. Building repairs.
7. Insurance and taxes on power house and machinery.
8. Wages of electrician and generator attendants.
9. Line repairs and renewals, wages and material.
10. Motor car repairs and renewels.
11. Motor car lubricants, waste, etc.

The extremely low cost per train mile given by Mr. Meier, both for cable and electricity, leads me to infer that some of the items enumerated above have been omitted. The following figures for three cable lines I know to be very close to the truth. I add Mr. Meier's figures by way of comparison. I have taken one-half the cost per train mile as that of the car mile on the assumption that the train consists of a grip and coach.

TABLE 1. COST PER CAR MILE FOR CABLE.

ROAD.	LOCATION.	TRAIN.	COST PER CAR MILE.	AUTHORITY
			CTS.	
A	St. Louis, Mo.	Grip car and 2 trailers.	2.662	W. Bartlett.
B	Kansas City, Mo.	Grip and 1 trailer.	3.295	W. Bartlett.
C	Kansas City, Mo.	Combination cars.	4.145	W. Bartlett.
D	St. Louis, Mo.	Grip and 1 trailer.	2.530	E. D. Meier.

TABLE 2. COST PER CAR MILE FOR ELECTRICITY.

ROAD.	COAL.	AT'NDANCE.	REAL ESTATE.	MACHIN'Y AND LINE.	OIL & WASTE	CTS.	AUTHORITY.
Washington.	0.720	2.500	0.330	1.800	0.200	5.550	O. T. Crosby
Richmond.	0.72	2.500	0.330	2.250	0.200	6.000	O. T. Crosby
Cleveland.	0.500	2.000	0.330	1.680	0.200	4.710	O. T. Crosby
Scranton.	0.028	2.500	0.330	1.830	0.200	4.180	O. T. Crosby
Louisville.						2.265	E. D. Meier
St. Louis.						1.760	E. D. Meier

I take the car mile as the unit of comparison, as it is about the only one that can be accurately obtained. The ton mile is theoretically the correct one, but the difficulty and expense attending its use make it undesirable.

In comparing the cost of motive power on different cable roads I prefer to double the train mile where combination cars are used to get the car miles, as the wages of gripmen and conductors are not considered, and the one combination car, as used on the roads under consideration, weighs about the same as one grip car and trailer.

Mr. Crosby's figures, as quoted, are given in detail in the *Electrical World* of December, 1889, page 405. A careful perusal of his article will show that he has included nothing which should have been omitted, and that his estimates are all sufficiently low. It is my opinion that the cost of "machinery and line" is lower than will be found in practice, as this item includes the repairs and renewals to the line, motors, and station machinery, which are liable to be underestimated. In fact, it is hardly possible to estimate the cost of these items at all. They should be taken from the expense account of the company, covering a period of one year or more.

MR. KEBBY:—I think Mr. Bartlett puts his figures too high for the commencement of the economic limit of cable roads, as I know of several roads which pay a fair dividend on a much smaller number of passengers per day. Two roads I have at present in mind which haul only 2,000 to 3,000 passengers per day.

MR. J. A. SEDDON:—The data here given for cable roads is very interesting; also the comparison of cable with electric roads. Of course, we all agree to the general proposition: "That each case requires consideration of its special features before deciding for operation by electricity or by cable." But I think, as a basis of making this discussion, some things should be borne in mind that have not been mentioned.

It is about four years since I have collected any data of cable roads, and then only with the special view of considering the efficiency of the system in transmitting the power of the engine to pulling the cars. At that time I concluded that the efficiency, or the ratio of the H. P. expended in pulling the cars to total H. P., had a range from about 0.10 to 0.45 for street roads; the Brooklyn Bridge cable being considered an exceptional case, with an efficiency of about 0.75.

There was only one cable road in St. Louis at that time and this had an efficiency of about 0.10 which was the worst; and about the best was the Market Street System of San Francisco, which I believe is also chargeable with a scrap heap account of over half a million dollars.

The above was originally only approximate data, and is simply given here in round numbers from memory, but contrasted with the 0.55 efficiency of Mr. Kebby's data, which I believe is about the results of the Olive Street Line in St. Louis and possibly of later roads, it will serve very well in the rough to show what the last five or six years have done in improving both the construction and operation of cable roads.

Now the point which I wish to make in the discussion is this; the cable road of which Mr. Kebby has given us the data, is the result of ten years of the special experience that can only be acquired through the intelligent study of the weak points developed in actual operation; nothing takes the place of working a machine to know its defects; while the electric roads with which a comparison is invited, have had no such opportunities. The present type is hardly two years old, while there has been so little opportunity of learning the need of, or making improvements, that we may practically class them all as the first construction.

The St. Louis electric roads just finished, when contrasted with the first cable road built here, would make a very strong showing in favor of the electric road; and that engineers will make improvements as they have in the cable roads is altogether a legitimate assumption. In fact all well developed systems can make a most favorable showing with new systems in their early stages, and contrasts unweighted by legitimately anticipated improvements would have ruled out electric lighting compared with gas, the railroad, compared with the stage coach; and even the steam engine compared with horse power; and with this view the contrast seems to me most favorable for electric roads.

For my own part I have little doubt that, except in special cases, where the grades, or heavy traffic necessitates a cable road, the changes in street roads in the near future will be altogether to electric roads. That is, provided overhead wires are allowed, which seems to be the present tendency.

Mr. Kebby:—Mr. Seddon prefaced his remarks by telling us that his information was four years old. I should have thought that it was a good deal more ancient than that. As to the efficiency of cable roads, or the percentage of the power generated at the engines used for hauling the cars, one road in St. Louis at the present time is using 60%, one is using 47% and one is using 46% for this purpose. The greater the number of cars

used on a cable road the larger is the percentage of the total power, generated at the engine, used for moving them. There are roads in San Francisco and Chicago which show as good results as those above. If these roads haul as many passengers as the Brooklyn Bridge they will show about the same results. That scrap heap which Mr. Seddon mentioned must have been piled up in somebody's brain. I was connected with the road mentioned when it was constructed and was in the city three years afterwards, and this is the first time I ever heard of it. Mr. Seddon's point is certainly well taken that electric roads have not been as long in use as the cable, but on the other hand there has been 2,600 miles of electric road built in the last four years, principally made up of small systems, and therefore there has been a very large number of electrical engineers and experts using their energies for the benefit of the systems, besides those engaged in electric light and power plants who have also turned their attention to street car propulsion whenever they had time to do so. The initial trip of cable railways was made on Clay street hill in San Francisco on August 1st, 1873, just about seventeen years ago. For about four or five years no other road was built and for several years longer the knowledge of cable roads was confined almost exclusively to San Francisco. So that the claim of infancy for electric roads has not got much the start of the cable system. I would also call Mr. Seddon's attention to the remarks of Mr. Geo. W. Mansfield, of the Thomson-Houston Co., before the street railway convention in Buffalo last October.

MR. J. J. AYER:—It seems to me that the question of comparative merit between cable and electric roads is fully answered by the showing made since their inauguration by the respective systems. During the last fifteen years there have been built and successfully operated about 350 miles of cable road, at the outside. Within the last two years there have been twenty-five hundred miles of electric roads built and are now in successful operation. That the various Street Railway Co's. have been able to change to the electric system by issuing bonds, which have been readily absorbed by capitalists at fair rates of interest and nominal discounts; that so many shrewd men, as the head of our street railway concerns are conceded to be, have selected the electric system to such a large extent and in such a brief period, is strong argument in favor of the electric railway. The improvement in the quality of street railway securities, due to the adoption of electricity as a motive power, is well known in all money markets to be very material. Now, if the experience with the crude apparatus which our manufacturers have had to offer has brought about the conditions that now exist, what have we to expect in the near future, when the brain and talent of our mechanics and electricians shall be brought to bear to produce an improved quality of apparatus, instead of having to work night and day, only to partially supply the enormous demand for such apparatus as they have been able to produce after practically only two years experience? It is a well, known fact that two manufacturers have equipped about 85 per cent of the electric railways in the country, and as there were less than 200 miles of electric railway two years ago, it goes without saying that their ability to

produce what they have sold must have been taxed enormously, and seriously delayed the adoption of obvious necessary improvements which have been apparent to the average motor men of a few weeks' experience. Notwithstanding the enormous expense of maintaining the motors and transmitting machinery as now constructed, the balance sheet must be, in almost every case quite satisfactory, as compared with other methods of propelling street cars. The fact that the first experience with electric apparatus on new roads is always the most expensive, due to the fact that all operators must be educated by the destruction of a certain amount of electrical apparatus at the company's expense, before they become proficient and able to properly care for the same, is a strong argument in its favor. While Jno. Stevenson, who has devoted his life to the production of street cars and the study of the business says, "The proper way to handle heavy traffic in large cities is by single cars and many of them, rather than in trains," I think the problem of transporting the public in our large cities has not been successfully solved, except where the roads with heavy traffic have run their cars in trains, rather than singly. When handling passengers by this method, it will undoubtedly prove economical to construct electric motor cars in an entirely different manner, by changing the position of the motor from the car truck to the platform, by constructing heavier and slower motioned motors, thereby doing away with the intermediate gearing now necessary with the high-speed motors, and large economy will be effected in the operation of the roads. The speed of car motors is now being reduced from 1,000 to 300 revolutions, enabling the motor to be geared directly to the axle, and greatly reducing the possibility of accidents to the motor armature. That such changes as this last mentioned and many others that have been known as practical, and yet not been adopted for some time past, was due to the character of the demand, which was not for the better apparatus, but for a larger quantity of such as was obtainable, so anxious were the street railway people to improve their condition. The cable roads of the country have had a much greater opportunity to demonstrate their comparative value, and yet, in large cities, the electric roads have distanced them. It is understood, of course, that for use in suburban towns and smaller cities, cable roads are not possible. It seems to me unnecessary to give comparative statements of relative costs of maintenance of electric and cable roads, providing it was possible to get the experience of companies maintaining the different systems, where the conditions are similiar; for the decision of the managers of the street railways of this country is overwhelmingly in favor of the electric road, as developed, crude as it is. With this judgment rendered to-day what may we expect, those of us who know the possibilities in sight for the electric motor as applied to the street railway, in the near future?

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

DECEMBER 9TH, 1890.—Club met at 8 P. M. with Vice-President Gobeille in the chair, and twenty members and three visitors present. The minutes of the last meeting were read and approved.

The Executive Board recommended for election to active membership Mr. Chas. W. Wasson.

Prof. Harry Fielding Reid, Ph. D., Prof. Arthur A. Skeels, Prof. Dayton, C. Miller, Mr. Thomas D. Owens and Roswell H. St. John were elected to active membership.

Mr. Mordecai for the Committee on Affiliation reported that no further action had been taken since the last report.

Mr. Warner for the committee on new Club Rooms reported that the present outlook indicates that the Club would be crowded out of its present quarters, that efforts had been made to secure new quarters in the old Bank building, but without success.

The Executive Board recommended a reception to be held some time in January, at which ladies should be invited.

Moved by Mr. Barber that the chair appoint a committee to make arrangements for the reception. Motion lost.

Mr. King, of Norwalk, O., was by vote invited to address the Club, and he occupied ten minutes in explaining some new discoveries he had made in pure mathematics.

The first paper of the evening was discussion of the "Injurious effects of Cement on Lime Mortar," which was opened by Mr. C. O. Arey and participated in by Messrs. Richardson, Eisenmann, Thompson, Hermann, Mordecai, and Morse. This was followed by a paper by Prof. C. L. Saunders on "Transmission of Power by Belt and Rope," which was followed by a discussion by Messrs. Roberts, Barber, Swasey, Eisenmann, Benjamin, Bowler, Hermann, and others.

On motion adjourned. A. H. PORTER, Sec'y.

ENGINEERS' CLUB OF ST. LOUIS.

339TH MEETING, JANUARY 7, 1891.—The club met at 8:15 P. M., at the Odd Fellows' building, President Burnet in the chair, and twenty-five members and two visitors present. The minutes of the 338th meeting were read and approved. The executive committee reported the doings of its 101st and 102d meetings.

Mr. Robert Moore suggested that the library of the late Mr. Whitman ought to be purchased for the club. Mr. Holman favored the plan, and spoke of the great value of the library.

Moved and carried that a committee of three be appointed to consider the question of the purchase of the library of the late Mr. Whitman. Messrs. E. D. Meier, Robert Moore and J. B. Johnson were appointed as the committee.

Prof. Johnson reported the receipt of a monograph on "The Rulo Bridge across the Missouri River," by George S. Morison, Chief Engineer. Moved and carried that the thanks of the club be extended to Messrs. Morison and Crosby for their donation.

Mr. J. A. Seddon then read the paper of the evening, on the "Economic Design of Settling Basins." After referring to some observations on settlement, which showed that the problem was to allow the water to stand undisturbed in open basins a certain time for the least cost. He pointed out the ridged method of determining the number of basins that should be constructed, and their length, breadth and depth respectively, but recommended that this ridged method should not be followed, on account of its being an extremely laborious process. He stated that the economic number of basins would probably be six; though there might be conditions where a system of five basins would be cheaper, but that this could be best determined by trial, and the changes of plan, if necessary, easily made after the general designs had been worked out. That under general conditions it would be safe to make the breadth of a basin two-thirds of its length, and as an approximation to determine the depth, the cost of the whole bottom might be taken as nine-twentieths of the amount available for the combined wall and bottom system together. That if it was desirable to make a closed check of the economic depth, it could be best determined by trial from the above as an approximation. In considering details in the design, he pointed out that though earth embankments with paved slopes would be considerably cheaper than masonry walls for enclosing the basins, yet for clearing water like that of the St. Louis intake, there were objections to them that unquestionably barred their use. Also for the St. Louis water, he pointed out that for cleaning the basins there should at least be only a small part of the bottom that had a less slope than 1.2 feet per 100 feet towards the central cleaning ditch: and that this ditch should be wide and shallow and have a slope of 1 foot per 100 feet. The paper further considered briefly some important requirements of the filling and drawing conduits, and the location and details of the filling and drawing chambers.

Discussion followed by Messrs. Russell, Holman, Ockerson, Wheeler, Johnson and Seddon.

The paper for the next meeting was announced, as follows: "Instructions for Topographical and Hydrographical Field Work on the Mississippi River," by J. A. Ockerson.

Adjourned. ARTHUR THACHER, Secretary.

The 340th meeting of the club was held Jan. 21, 1891, at the Odd Fellows' building, Vice-President Eayrs in the chair, with twenty-four members and two visitors present. In the absence of the Secretary, H. A. Wheeler was elected to temporarily fill the vacancy. The minutes of the 339th meeting were read and approved.

The applications for membership of David Albert Molitor and Robert Lee Faris were read and referred to the executive committee.

A letter was read from the secretary of the Board of Managers of the Engineering Societies giving the subscriptions to the Journal by the different clubs of the Association.

The paper of the evening was read by Mr. Henry for the author, Mr. J. A. Ockerson, Chief Assistant Engineer of the Mississippi River Commission, on "Instructions for Topographical and Hydrographical Field Work" on the surveys of the Mississippi River.

The objects of the survey as set forth are to obtain sufficient data for an accurate topographical and hydrographical map, which may be used in studying the physical characteristics of the river, planning improvements, and also serve as a basis for future surveys by means of which the changes in bed and banks may be ascertained and their causes and effects studied.

The instructions are the result of several years' experience on the survey of the lower river, and they set forth in detail the character of the work required, the limits of error admissible and forms in which notes are kept.

Where the secondary triangulation points are more than two miles apart, a tertiary system is carried by means of which points are fixed at intervals of a mile or less on both sides of the river. This system begins and closes on a known side of the secondary system. The discrepancy should not exceed 1 in 3,000.

Lines of permanent marks are fixed at intervals of about three miles along the

river. These lines are nearly normal to the river, and on each line there are placed four marks consisting of a flat stone, 4×18×18 inches, placed 3 feet below the surface of the ground, on which is placed a 4-inch iron pipe, projecting a foot or more above the surface of the ground. The top of the pipe is covered with a removable cap properly marked. This is believed to be the most stable mark that can be used with moderate expense, the cost being about $2.50 each.

These marks are carefully located and the position and elevation well determined, and thus form the basis for comparison between all future surveys.

The detailed topography covers a strip about three-fourths mile wide on each side of the river. Outlines of lakes, large streams, etc., are located when within ten miles of river.

All points are located with transit and stadia, the elevations being determined by vertical angles. On the bottom lands 5 foot contour lines are developed, and on bluffs 20 foot contours.

The maximum distance that may be read with stadia between stakes is fixed at 500 metres.

The discrepancies admissible should never exceed 0 degrees .05 minutes in azimuth, 1 in 5 0 in distances, and one foot in elevation for the longest distance.

A line of levels is run along each bank of the river, and the elevations of all permanent marks, slope of the river, etc., are thus determined. These lines check on one another by means of river crossings at intervals of about three miles. All lines not otherwise checked are duplicated. The errors of closure should not in any case exceed 0.2 feet.

Soundings are taken along lines normal to the stream. These lines are about 250 metres apart, and the soundings on them are taken as rapidly as the leadsman can operate, with the boat moving slowly.

The soundings are located by two sextants in the boat reading to known points on shore. A longitudinal line along the thread of the channel is also sounded.

In order to avoid the confusion arising from calling similar objects by different names, a nomenclature is given, defining the natural objects to which certain names should be applied.

Blue prints showing the kind of permanent survey marks used were exhibited, and also two published maps of the Mississippi river, showing the results of Mr. Ockerson's mechanical methods of printing signs and letters on maps. Better results are obtained than hy the ordinary pen method, and the mapping of the surveys made by the Mississippi River Commission is now done by the mechanical process.

The paper was discussed by Mr. Eayrs, who mentioned using the jack chain for sounding as being more convenient than a line, from its freedom from skrinking or stretching.

Mr. J. A. Seddons also gave some experiences on the accuracy of sounding with lines, especially in strong currents.

The paper for the next meeting by Prof. Howe on "Some Experiments on the Strength of Vitrified Sewer Pipe" was then announced, after which the club adjourned.

H. A. WHEELER, Sec'y. pro tem.

WESTERN SOCIETY OF ENGINEERS.

JANUARY 7, 1891. The Annual Meeting (277th) of the Society was held at the Sherman House, at 7:30 p. m., January 7th, 1891. President L. E. Cooley took the chair and there were some 120 members and guests present.

The Secretary read the programme as printed in the December proceedings, and by consent the reading of minutes of last meeting were dispensed with.

The President, before naming the tellers to count the vote for officers for 1891, called for any ballots that might not have been already polled. The tellers appointed were Messrs. L. P. Morehouse, E. C. Carter and A. F. Robinson.

The Secretary presented the names of the following new members: Stuyvesant Fish, Chas. L. Harrison, Benj. Worthaupter, Jacob T. Wainwright, Robt. I. Sloan, Jas. B. Williams, Dwight C. Morgan, Jos. K. Freitag, Benj. S. Crocker, Lincoln Bush, Jas. H. Hicks, Geo. A. Butler, Walter L. Webb, Albert H. Wolf, Jacob F. Foster, Warren R. Roberts, Robt. C. Randolph, Warren C. Smith, Paul Willis, Harry M. Jewett, Willis S. Jones, Robt. B. Seymour, Wm. Kissack, Wm. G. Potter, E. R. Schnable.

Letters of regret were read from Hon. Ben. Butterworth, Thos. B. Bryan, Lyman J. Gage, D. H Burnham, Gen. John Newton, Col. Geo. R. Davis, W. A. Otis, Hon. John T. Dickinson and Joseph R. Dunlap.

The Secretary then presented the following:

SECRETARY'S REPORT FOR 1890.

Mr. President and Members of the Society:

The present membership of the Society numbers 351. At the annual meeting of 1889 the gross membership was 255. I regret, however, to say that there are seven resignations to be acted upon at the next meeting of the Board of Directors, which will reduce our membership to 344. But as the figures I have given for our last annual meeting includes fifteen resignations not then acted upon, we have for our present membership 344 as against 240, leaving us a net gain on the last year of 104 new members, a fact I offer you for consideration in respect to the material progress of the Society.

I am very happy to say we have met with no loss of membership by death during the past year.

Interest in the Society's work cannot be more suggestively emphasized than by the attendance of members, visitors and the press at its periodical meetings. In this respect the record of the Society for 1890 presents a remarkable contrast even with that of the year 1889, which in turn was a great improvement on previous years.

The average attendance at the meeting of 1890 has exceeded sixty persons. On several occasions the rooms have been uncomfortably filled, and this warrants me in bringing to the notice of the Society the necessity of giving early attention to the question of more commodious quarters. A committee on permanent quarters should be nominated at an early date which, as our present lease terminates on May 1st, 1892, can be profitably engaged in giving this important question sufficient and timely consideration to ensure practical and permanent results.

During no year of the Society's existence has the work of the Society been so broad and of so diverse interest as that of the year 1890. During that period the following subjects have been taken up and discussed:

The Paris Exposition of 1889, a paper by Mr. O. Chanute.

Mr. E. S. Jenison's design for an Exposition Building.

The Chicago Railway Problem, occupying two evenings, and comprising papers by Messrs. A. F. Robinson, Richard P. Morgan, Max E. Schmidt and Ossian Guthrie.

The World's Fair Site, with short papers by Isham Randolph, Richard P. Morgan and T. T. Johnston.

Interlocking Signal Devices, by Mr. Isham Randolph.

The State and the Railroads, by Mr. L. P. Morehouse,.

Dr. de Bausset's "Aeroplane," by Mr. Otis K. Stuart, member of American Institute of Electrical Engineers.

A Multiple Dispatch Railway, by Mr. Max E. Schmidt.

In addition to the above subjects, which all received valuable discussion, the question of the Affiliation of Engineering Societies formed the subject of a report by a committee consisting of Messrs. Benezette Williams, A. Gottlieb, O. Chanute, H. B. Herr and A. F. Nagle.

Committees have been appointed on the following important lines:

National Public Works.

Bridge Legislation.

Practice of Sanitary Engineering.

Municipal Public Works.

Topographical and Cadastral Survey of Illinois.

The Railway Problem of Chicago.

The Society has had gratifying progress reports from the Committees on Bridge Legislation and The Railway Problem of Chicago.

I believe the Society may justly congratulate itself on the success of its Committee's work on an International Congress of Engineers and Joint Engineering Headquarters for the World's Columbian Exposition, 1893. This was inaugurated by Mr. E. L. Corthell, who, with other members of our committee, will, we may fully expect, bring the matter to a successful issue. A majority of the Societies invited to cooperate have, as far as we may judge, entered into the project with commendable enthusiasm. The committee will, perhaps, permit me to say that they expect very soon to call another joint meeting to put the whole undertaking on a working basis.

I think it may truly be said, looking over the records of the work of the Western Society of Engineers for the year 1890, that for practical and valuable work the record will be hard to surpass.

FINANCIAL STATEMENT FOR 1890.

Receipts.

Cash—Fees and dues from Members (the only source of revenue)		$3299.50

Disbursements.

Amount due Treasurer from 1889	$ 8.62	
Journal of the Association of Engineering Societies	754.70	
Secretary's salary	1200.00	
Rent—9 months' rent, 13 months' janitor	561.00	
Printing	262.30	
Stationery and Stamps	85.41	
Stenographer	47.00	
Insurance	40.00	
Expense of Board of Managers	49.27	
Sundries, furniture, etc	35.20	
Annual Meeting	256.00	
		$3299.50

Jan. 7, 1891.

We have examined the Treasurer's books and vouchers and compared them with the above statement and find it to be correct.

ROBT. A. SHAILER,
WM. R. NORTHWAY,
Committee.

Extending the above I would add that there remains on the books of the Society to be collected some 700 dollars, and we have bills to be met amounting to about $350, so that, considering all things, the financial condition of the Society is sound.

With regard to the future I would say, that allowing for an increase of 25 per cent. on our membership for the current year, we may reasonably expect an income in the neighborhood of $4250, and from a careful calculation of all possible necessary expenses, $3900 should amply meet all exigencies.

With regard to our Library I would say that it should be increased and an effort made to demonstrate its utility. This might form a useful work for a committee and I would suggest that as a matter for current action.

In concluding my brief remarks I would add that the subject of some appropriate certificate, or method of honoring our life members has been suggested to me, and also the matter of a badge or pin as a particular means of recognition of the members of the Western Society of Engineers. This has been offered by several members at various times.

I cannot finally conclude without cordially thanking the officers and members of the Society for the invaluable help they have at all times tendered me in my work of Secretary of the Society and the duties pertaining to that office.

The President called for remarks on the Secretary's report, or any matter pertinent to the occasion.

Mr. Isham Randolph moved that the report of the Secretary be received and placed on file—motion seconded and carried.

Mr. James D. McKee, through the Secretary, presented a pin or badge as a distinguishing sign of membership in the Western Society for consideration of the members.

Mr. Randolph moved that a committee of three be appointed to consider the question of a pin or badge for the Society, and that the badge introduced by Mr. McKee be submitted to that committee. Seconded and carried.

The vote being heavy and there being no possibility of the tellers getting through their duties for some time, President Cooley read a carefully prepared address on "The Modern Spirit of the Engineering Profession." The address is printed in this issue of the JOURNAL.

Prior to the reading of the report of tellers, Mr. John Lundie requested the Secretary to state that he wanted it distinctly understood that he had declined the candidacy for Secretary.

The result of the ballot for officers for 1891 was as follows:

For President, 191 votes cast: L. E. Cooley 145, Chas. FitzSimons, 44, B. Williams 1, C. L. Strobel 1. For 1st Vice-President, 161 votes cast: J. F. Wallace 82, H. B. Herr 79. For 2nd Vice-President, 160 votes cast: W. O. Seymour 81, A. J. Tullock 77, G. A. M. Liljencrantz 2. For Secretary, 189 votes cast: John W. Weston 154, John Lundie 35. For Trustee, 148 votes cast: O. Chanute 130, Fred Davis 18.

Mr. L. P. Morehouse explained that the discrepancy in the vote for First Vice-President of 30 is due to the fact that a great many voted for both candidates on the ticket, which votes could not be counted.

Short speeches of thanks were made by the officers elect.

President Cooley then called upon Gen. Chas. FitzSimons, who said-

Mr. President and Gentlemen of the Western Society of Engineers, this it seems to me is a most unusual way of putting things. The President in his address told us of a great many accomplishments that an engineer ought to attain in order to be a full-fledged member of the profession, but really, this looks like a low-down political trick. Surely, the dead should be allowed to rest in peace. I had a speech prepared, which I have left in the cloak-room, and in revenge for your not electing me I refuse to read it. I can only say, however, that you have done a great deal better in electing your present, scholarly, energetic and accomplished president. To show you that I feel that, I want to make it more emphatic by moving that the election of Mr. Cooley be made unanimous. (Motion seconded). Gentlemen, you have heard the motion, all those in favor of this motion will signify it by saying aye. The ayes have it.

Mr. Corthell delivered an address on "From the Unsalted Seas to the Briny Deep," which will be given in the next issue of the JOURNAL.

The president then called upon Mr. O. Chanute to say something on Aerial Navigation.

MR. CHANUTE:—The subject is not of my choosing, but I have laid myself open to being selected to speak on this topic by discussing it at the last meeting of the Society. I suppose the committee said to themselves, here is a man with a crotchet, we will have some fun with him, for I acknowledge that I do believe that it is not entirely impossible that the century which has seen the development of the steamer and the railway may yet see a successful attempt to navigate the air. But I have several other reasons for responding on this subject to-night, one of them being that it seems appropriate after supper to discuss a subject which proposes to abolish gravity, and another is that I feel sure that if any professional men are entitled to wear wings, they are the civil engineers. I can see great conveniences in this mode of traveling. In making preliminary surveys, for instance, I can see that an engineer soaring over the country with a "Kodak" would have great advantage over the present tedious method of plodding along on the ground, and I also see that for exploring inaccessible places, an engineer fluttering around the edges of a precipice with a barometer strapped to his back, as well as a pair of wings, would have great facilities over the present method of being let down with a rope. That in cross sec-

tioning cuts a tapeman with a long pair of wings might fly up to the top and materially shorten the time required for the operation, etc., etc. The principal difficulty hitherto has been the lack of adequate motive power; that is the want of a sufficiently light motor in proportion to its energy, to accomplish what birds daily perform, but during the past two months announcements have come from three different parts of the world that very much lighter motors than any now known to exist are being developed and are being made a partial success. From France comes the statement that Commandent Renard, who has charge of the Aeronautical department of the French army, and who, as you remember, some years ago accomplished a speed of fourteen miles an hour in a navigable balloon, with an engine exerting nine horse power and weighing 1,174 pounds, has now developed another motor from which he obtains seventy horse power, with a weight of but 946 pounds, or a weight of only 13½ pounds to the horse power.

From England comes the news that Mr. Maxim, who is celebrated as an inventor of an electric light and also of that marvel, the quick-firing gun which fires 100 shots a minute, has invented a motor of 100 horse power which only weighs 600 pounds. From our own State comes a still more wonderful fairy tale: from Mount Carmel comes the information that a gas motor has been invented which exerts 100 horse power and only weighs 250 pounds. Now, remembering all the time that the solution of the problem is chiefly dependent on a light motor—if one-half of the story of Mount Carmel be true, and we can obtain fifty horse power with 250 pounds of weight, or even if a quater be true, or to speak more accurately and professionly, if only the square root of it be true, and we can get a motor of ten horse power weighing only 250 pounds, then an enormous step will have been made towards the solution of the problem. It is said by the newspapers—I am glad to see the reporters are all gone—that within the next three weeks the first trial trip will be taken from Mount Carmel to our own Chicago, and thence to the seaboard, and that there is some foundation for these reports would appear from the fact that in the last advices that we have from Mount Carmel it is stated that a number of post holes have been dug for the enclosing fence, and that the office furniture is being ordered. This, I think, indicates the good hope that perhaps the present generation will see the beginning of the solution of the problem, and it is not impossible that to the future Annual Meeting our members will come, not only by rail or by water, but perhaps in flying machines through the air.

Mr. E. L. Corthell, now occuping the chair, said: Gentlemen we have with us tonight an old triend, a gentleman that some of us have known many years, with whom we have had many good times, who was always ready to be with the boys when we have had our annual meetings, Mr. Wm. E. Worthen.

Mr. Worthen:—In the course of his remarks said: Gentlemen, I was given the assurance that there would not be any speaking for me to-night. Had he given me notice I could have brought a book too. I do not think it belongs to an engineer to make long speeches, but I may give you some information and some little advice. I have been longer in the profession than probably you are old, most of you.

My first trip was in 1847. I had made up my mind I would settle West, and we came to Cumberland and than took a stage to Brownsville on the Monongahela, and then we went down the Ohio and up to St. Louis; then from St. Louis I went up to Galena, and we came across by stage from Galena to Chicago. There was one incident connected with that trip which struck me forcibly. We tipped over, only once, that was very unusual in its fewness, and the stage driver got caught under the boot, and was hurt somewhat. I fortunately had a flask of brandy which I carried around with me, on account of the water. I had not touched that brandy at all, but I bent down and stripped the man's leg, where we found a considerable bruise; I took an old flannel shirt and rubbed this brandy in as hard as I could, and he said, "Would you let me taste that brandy?" I let him taste, and says he, "You need not put any more on my leg." We came to Chicago and stopped at the Tremont House, I believe it was where the present Tremont House is, but it was a very small hostelry and not much of one, I recollect, and I returned via the lakes to Buffalo.

There is one thing I want to say to you gentlemen: I have been long enough in the profession to understand something about in. I graduated from college, not

with high honors, but I was midway in the class and I thought that was enough; when I got out of college I had no instruction, what you might call instruction pertaining to the profession. I learned geometry, calculus and such things; but no practical things, and when I left I had to begin to learn what I did not get there, and I had no facilities except by observation At the present time you young men come out full-fledged, and generally you will find that you know a great deal more than I do. A man that comes out of these technical institutes comes out a learned man, but he never comes out an engineer unless he works. It is not the good tools that make a good workman. I have seen many a carpenter with a long jointer, trying to get a smooth surface straight, when a smaller implement would do just as well. It is the use of material that makes the workman. And let me advise you again, there is no man who cannot learn something all the days of his life. Accumulate your facts as much as possible. There is no workman, however low, no matter whether he works with a shovel or hoe, from whom you cannot get hints. That is the way my bread has been made. I started to be a hydraulic engineer, that was my great admiration, but hydraulic engineering would not support me. That failed, then I went into a railroad; I began away down, went through the construction and afterwards was manager of the road and vice-president of the New Jersey & New York Road. I came to New York and opened an office for hydraulic engineering, and for seven years I never had an application; they hadn't got up as high as that. I took up architecture. I built two or three houses and that sort of thing and about that time I took charge of a cotton mill and machine shop, and after that I got back to hydraulic engineering, and that has been the course of my life. In my time you could not have a specialty. You had got to take your business as it came, and so of course I accumulated, not much money, that is not part of engineering, but a great deal of knowledge can be collected in that way. If you only keep your eyes open and are not afraid of the source from which you get your information you may live as long as I and pick up more.

Mr. Corthell:—We have with us another past president of the American Society and a very honored member of our Society, from whom we will be pleased to hear a few remarks.

Mr. D J. Whittemore, after relating some amusing reminiscences, said:

Forty-three years ago an old lady in one of the New England States bordering the province line, was told to look out of the window and see a civil engineer who was passing. This she did and then exclaimed, "How much like a human being he does look," That this is fact I am assured, as the incident was told me by her husband. who was not only an exemplary deacon of the church but also one of the most notorious smugglers on the border.

Two hundred years ago the designation "Civil Engineer" was unknown to our vocabulary, and it can be said that our grand calling could only be designated as a profession, having for its object the consideration and determination of the economic use of time, power and matter for the purposes of man, after securing somewhat that definite knowledge of things and natural law that has come to us during the years mentioned. Honorable as the profession may be, and loving it as we all do, yet I think you will agree with me in the opinion that the profession has not that high estimation with our people or even among many of our members, that it has in Europe, and perhaps this is owing to faults of our own or rather faults of our methods of service.

A large majority of us spend the greater share of our professional lives as the salaried employees of corporations. I venture to say that should the merchant give to his vocation as much thought and work as the engineer gives to his employers' interest, success would oftener attend his efforts. The engineer's best efforts are for others, and he has little time to think of personal advancement or pecuniary preferment.

I hail with pleasure the rapid increase in the number of consulting engineers in our country,—men whose services cannot be commanded for a small stipend per month throughout successive years. It cannot be said that this departure is a failure. You have ample testimony of the success of many of your own members, whose services are in demand as consulting engineers.

No doubt it is honorable to be considered the chief engineer of a railway company or of a city, yet we can cite instances where the chief of police of a corporation secures a greater compensation than the engineer in chief: in fact, it may be said that one of the ablest engineers that our continent has ever known, was crowded or rather starved out of his position in a city not one thousand miles from where we are now. It is but natural that engineering societies like ours, are formed for the intellectual improvement of its members; yet I take it that you have observed a tendency to make such institutions, to some considerable extent, eleemosynary in character. What I allude to is, that when there is a great engineering question to be solved, in which either the public or corporation have great interest at stake, some one or more members will suggest the formation of a society committee to report upon and solve the question. In the knowledge that many of our ablest members favor such society action, and having the highest regard for their opinions on purely engineering questions, I wish on this occasion to say that I am utterly opposed to such committee action. If the public wants an opinion on a purely engineering question, let the public pay for it.

By such society action attested by that night-mare seal of ours, we arrest individual effort and employment. Again, that which costs nothing to the party served is too often worth nothing. Again, such committee action may be fostered by persons pecuniarly interested in some pet scheme. I would instead urge each and every member to give our society papers upon subjects in which he or they are interested, and no doubt they would be fully and freely discussed by our members, and then leave the matter without further society action.

If we could inject the lymph of all human knowledge, present and prospective, into a committee of our society, then we could make engineering easy as a pursuit: in fact, could abolish our profession and depend upon a clerk of works in our constructions. If, however, a member desires to give us a paper upon how to build better or poorer bridges than we do build, if he desires to show us how it is possible to construct a system to impound the sewerage of the city of Chicago within its corporate limits, or to exclude it from said limits, by all means encourage his efforts, but let no committee of the society overshadow an individual effort in this direction.

I wish you to understand that my motive in thus speaking is not mercenary in nature or design. We should all try and dignify our profession by insisting that proper recognition and compensation is due the engineer for his work.

As a class, the engineer is not overburdened with worldly goods, and perhaps it is well that this is so. I do not know of one of our profession who has made himself a millionaire by his calling,—present company of course excepted: neither do I know of the son of a millionaire who has succeeded in becoming an accomplished civil engineer,—again, present company excepted. Love the profession dearly as we may, it needs all the incentive that poverty can bring to make many of us follow it through life. Notwithstanding this, I would rather that a son of mine should be an engineer with aspirations to have an establishment of his own creation in time, than without this acquirement and aspiration, to leave him a million with all that it might entail. With the former, he might hope that when his life work was done his epitaph would be, "He was an Engineer," and coming generations could truthfully say that this world was better by reason of his work.

MR. E. L. CORTHELL:—Gentlemen, it is getting very late. We have quite a number here from whom we would like to hear something, but we will not keep you for it. There is one gentleman here, a stranger, and yet not a stranger, from the East, whom we all know by reputation and many know personally. He is our guest this evening, and we would like to hear from Mr. Wellington.

MR. WELLINGTON:—In declining to speak by reason of the hour he referred to the very humorous story by Edward Everett Hale, "How I was undone and who undid me," and quoting said: There has been so much said that was good, that I will not detain the company to make any further remarks.

MR. CORTHELL:—Gentlemen, we have been very highly entertained to-night by members of the Apollo Club, and I think it is due to them for their kindness that we offer a vote of thanks.

Moved and seconded that we vote thanks to the members of the Appollo Club. Carried.

The annual meeting then came to a close, at midnight, and it was declared to have been most enjoyable, successful and gratifying.

JOHN W. WESTON, Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

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IN MEMORIAM.

BENJAMIN H. GREENE, DIED JANUARY 4, 1890.

[Montana Society of Civil Engineers, December 20, 1890.]

Benjamin Henry Greene was born near Georgetown, South Carolina, September 17, 1829, and was the second son of John F. Greene, a rice planter on Black River. He was one of a dozen brothers and sisters, ten of whom reached maturity, and Benjamin's death is the first break in their ranks.

The Southern branch of the Greene family trace their ancestry back some 200 years. The founder, Wm. Greene, emigrated from Rhode Island about the middle of the 17th century, where having quarrelled with his kindred, he cut the final "e" from his name* to show that he disowned them, shook the dust of the colony from his feet, and took his way to the Bermuda Islands. Here he married, and accompanied by his wife emigrated to the colony of South Carolina, and finally settled on Black River. There was but one white man there before him and between them they laid claim to the country far and wide.

At the breaking out of the Revolutionary War the Greens were ardent Whigs, and the particular branch of the family from which Benjamin was descended, fought to a man under General Francis Marion, the famous "Swamp Fox."

When Ben was quite an infant his parents moved to Darien, Georgia, where his father had purchased a rice plantation on the Altamaha. There

*Just before the late Civil War a number of his descendants held a caucus and proposed to resume the "e." This was only partly agreed to, so now the name is spelt both ways.

he passed the first fifteen years of his life. In the fall of 1844 he was sent to the preparatory school of Emory College at Oxford, Georgia, but upon examination he was found prepared to enter college in all the studies except Greek, so devoting himself to that branch he was in a short time admitted to the Freshman Class. Among his college mates here was L. Q. C. Lamar, now Associate Justice of the Supreme Court of the United States, between whom and himself a friendship sprung up which lasted through life. It was to Mr. Lamar, then Secretary of the Interior in President Cleveland's Cabinet, that he owed his appointment as United States Surveyor General for Montana.

He remained at Oxford two years when his father transferred him to Columbia College, South Carolina, feeling a pride in having his son graduate from the University of his native State.

When he left Columbia in 1848 he joined the family at their new home in northern Georgia where his father had purchased a large farm, "En Cerro," near Resaca, where years afterwards, was fought one of the fiercest battles of the war.

In November, 1848, Ben commenced his engineering life on the Nashville and Chattanooga Railroad, where he remained up to its completion in 1852. From this road he went with his friend and chief, Geo. H. Hazelhurst, to the survey of the Aberdeen and Nashville division of the New Orleans and Jackson Railroad, and thence, in the fall of 1852, to that of the Nashville and Madrid Bend on the Mississippi.

Having completed this work he accepted an offer to go upon the survey of the Louisville and Nashville Road, where he remained until the spring of 1853. A severe illness now compelled him to give up the field for several months, but after recuperating at home, he returned in the fall to Tennessee, and engaged on a road from Tullahoma to McMinnville. In 1854 he was on the New Orleans and Jackson Railroad, that portion of it under construction between the Louisiana State Line and Jackson, Mississippi, and on this road he remained until 1857.

In the fall of 1857 he took charge of a road in Tennessee, from Nashville to Madrid Bend, which he had surveyed some years before.

In the winter of 1857-8 he went to Cuba on the invitation of some parties interested in building a road there; at that time there was but one railroad on the Island. The scheme fell through, however, and he returned to the United States.

During March of 1858 he married Miss Sallie Skipwith, of Jackson, Mississippi, a daughter of Mr. George Skipwith, a grandson of General Nathaniel Greene of Revolutionary fame, and going to Georgia, spent the summer among his relatives.

During 1858 and 1859 he was engaged as an Assistant Engineer upon the construction of the New Orleans, Jackson and Great Northern Railroad, extending from New Orleans, Louisiana, to Canton, Mississippi, and now a part of the Illinois Central system. He was identified with this enterprise from its inception, acquitting himself with credit and was highly endorsed by George H. Hazelhurst, his chief, whose lifelong friend he became.

During the winter of 1859 he suffered the loss of his wife, who died at Jackson, Mississippi. Among her many accomplishments charity was foremost and she was sadly missed by the poor.

In 1859 he was elected Chief Engineer of what was denominated the "Gulf and Ship Island Railroad," a scheme which had its origin in the Mississippi Legislature, and was designed especially to build up a seaport on the Gulf Coast of that State. This road was to have been built at the expense of the State and the funds necessary to carry on the surveys were raised by appropriation.

Two independent surveys were made from Mississippi City on the Gulf to Canton in the upper part of the State. Also elaborate maps, profiles and estimates of the cost of construction—the work lasting until the spring of 1860, about which time the appropriation became exhausted, and all further work was suspended. The stormy presidential canvass of that year, followed by the inauguration of hostilities the next, gave a quietus to the Gulf and Ship Island Railroad, from which it never recovered, although various desultory efforts have been made to revive it.

In the spring of 1860 he attended the famous Democratic Convention held at Charleston, South Carolina, and that summer he spent traveling through the North and Canada.

Major Greene was connected with the Army of Northern Virginia, C. S. A., throughout the war and filled with distinction the positions of Division and Assistant Inspector General and that of Chief Engineer of the Second Army Corps. In August of 1864 he was captured and sent to Camp Chase, where he remained six months. He served successively upon the staffs of Generals Ewell, Early and Gordon, who all bear testimony to the characteristic traits of activity, zeal, courage and cheerfulness which distinguished him throughout his life.

General J. B. Gordon in speaking of him, says: "I knew Major Ben H. Greene well, both while he served on General Ewell's staff and on my own. I have seen him in the most trying and responsible positions, on the march, in the camps and under fire in battle. No more reliable, resolute, devoted or brave soldier, in my opinion, was in General Lee's army. He was a man of singular cheerfulness under all trials—full of hope and faith to the last of the struggle. His courage was of that enthusiastic character which was always an inspiration to others. I honored and loved him."

It is to be regretted that the army reminiscences of Major Greene cannot well be given here in full, as they would certainly prove most interesting to his numerous friends throughout all sections. That he led an active and hazardous life during this period can well be understood, when it is known that he was attached to Stonewall Jackson's command and was present at all the great battles fought by that General and by his successors Generals Ewell and Early.

The dangerous missions he accomplished and his miraculous escapes from death would almost lead to the belief that he enjoyed a charmed life, having been shot over the heart at one time by a sharpshooter and falling from his horse was left by the staff—then galloping over the field—as dead, being alone saved from death by a note book and his watch, the

bullet having penetrated the former and expended its force upon the edge of the watch—which was forced partly between his ribs.

On three different battlefields his horse was shot under him, "Ah, and they were beautiful horses too," he would say when recounting his escapes. Numerous incidents in his army life bear evidence of that noble sympathy for the distressed and unfortunate for which he was so universally loved and which he extended to either friend or foe whenever conditions prompted.

At the close of the war, in 1865, General Beauregard, then President of the New Orleans, Jackson & Great Northern Railroad, appointed Major Greene Superintendent of that road—the line upon which he had spent several years of his life in constructing. He combined with its superintendency, the duties of Chief Engineer as well, and his acquirements as such were brought into active play, by reason of the wretched condition of the roadway.

It had been torn up repeatedly by contending armies, to bar the progress of their adversaries—the cross-ties and bridges were in a sadly demoralized condition and with the exception of the grading, to put it in working order was almost equivalent to building it anew. All these duties Major Greene performed to the satisfaction of his superior officers.

His incumbency of this position extended over the period from about the fall of 1865 to that of 1866, when he was elected by the Levee Board of the State of Louisiana, Chief Engineer of the Lower Division of the Louisiana Levees.

This latter position was a particularly onerous and responsible one. The Levees, lining the banks of the Mississippi River from New Orleans to the Arkansas State Line, had been utterly neglected throughout the period of the war. Great gaps existed at frequent intervals along their whole extent, and adjoining plantations were, with few exceptions, completely at the mercy of the overcharged waters of the river.

The State went to work with the utmost vigor and at an immense expenditure of money to repair these breaks, which was done as rapidly as possible; but the accumulated waters, due to the spring freshets above, rushing down and piling up against the freshly built embankments, swept them away in numerous instances in defiance of man, money, and the best engineering skill. Crevasses were occurring constantly, and at numberless points where they did not occur, armies of men had to be kept on constant duty day and night, in fair weather and in foul, watching the weak points and strengthening them when necessary.

In this battle with the elements, Major Greene was always conspicuous, exposing himself in all kinds of weather, frequently up to his boot tops in mud and water, often in heavy rains, but encouraging his men, both by precept and example, at every point that needed his presence.

During 1868 the New Orleans & Jackson Railroad Company, under the management of General Beauregard, was contemplating an extension of their road via Aberdeen, Mississippi, in a northeasterly direction into Tennessee, and Major Greene was selected to survey and locate the line rom Aberdeen to Decatur, Tennessee. So far as any practical results were

concerned, his labors were wasted. No further steps were taken by the company at that time to push the enterprise, and Major Greene soon found himself open for another engagement, which was not long in presenting itself.

A company had been organized in Natchez to build a line of railway to connect that city with Jackson, the Capitol of the State, and the Major was offered charge as Chief Engineer. Two lines were run between the points named, and the time so employed with the incidental office work which followed, consumed the remainder of the year 1869. This scheme was likewise suspended and lay dormant for a number of years, although the road is now completed.

On November 4th, 1869, Major Greene married Miss Emmeline Dabney, a daughter of Colonel Thomas S. Dabney, a cotton planter of Mississippi, whose noble life has been so graphically portrayed by his daughter, Mrs. Smedes, in her " Memorials of a Southern Planter."

About the years 1870 and 1871, the New Orleans, Baton Rouge & Vicksburg (or Backbone) Railroad scheme was developed, an enterprise based largely upon the prospect of securing certain lands within the State of Louisiana, set aside by the General Government for the purpose of fostering works of internal improvement.

Major Greene was employed to organize a party and make the preliminary surveys. The original charter confined their operations to the East side of the Mississippi River, but this was afterwards so altered or amended as to embrace a line on the West side of the river up to the mouth of Red River and thence on the West of that stream to Shreveport, Louisiana. This latter line was subsequently constructed under the name of the New Orleans Pacific Railway, and now constitutes the Louisiana Division of the Texas & Pacific Railroad.

Major Greene was in the employ of the promoters of the New Orleans, Baton Rouge & Vicksburg Railroad for some time. He surveyed more or less of the proposed route between New Orleans and Vicksburg, made some location and did some grading in the immediate vicinity of Baton Rouge.

This scheme, like so many others in the Southwest at that time, collapsed, or at least became dormant. It was subsequently revived in 1875 by citizens of New Orleans, who organized what was called the New Orleans Pacific Railway Company, with Mr. E. B. Wheelock at the head, the object being to connect New Orleans with Marshall, Texas, and Shreveport, Louisiana, one or both. Major Greene was appointed Chief Engineer.

Previous to that time, and during the years 1872-3 and 4, the Major was at times unemployed and at others engaged in business enterprises of a minor character. Among other engagements of the kind, he made a short survey for a branch line from the town of Liberty, in Mississippi, to Summit, a station on the New Orleans & Jackson Railroad, which line was never built. He also laid off the town of East McComb, adjoining McComb City, Mississippi, and was engaged for a while as Assistant City Surveyor in the New Orleans Department of Public Improvements.

It was sometime during the year 1875 that the surveys of the New Or-

leans Pacific Railway were commenced, and the work was prosecuted in a desultory way until the spring or summer of 1879, when the company's resources became exhausted and the work was suspended.

In the meanwhile a location was made both to Marshall and Shreveport, and the line was graded to a point some 15 or 20 miles north of Natchitoches. He was shortly afterwards appointed Chief of the Louisiana Board of State Engineers and surrendered that position to assume control of and complete his old road, the New Orleans Pacific.

During the summer of 1880, a syndicate of northern capitalists, of which Mr. Jay Gould was the head, organized the American Railway Improvement Company and entered into contract with the New Orleans Pacific Railway Company for the construction of that line from New Orleans to Shreveport, Louisiana. Major Greene was appointed the Chief Engineer of the Improvement Company and was given the management of the work in all the department. This was probably the most important and responsible professional engagement he had yet undertaken.

He was given an unlimited order to draw upon the New York office for all the funds necessary to complete the road, which contemplated an expenditure of some $5,000,000.

This work was beset with many obstacles and brought into full play all his characteristic energies and well known executive ability. A large portion of the line lay through the swamps and lowlands of Louisiana, and the wet winter season of 1880 and 1881, preventing the contractors on the Shreveport Division from finishing more than about ten per cent of their contracts, at the date provided for their expiration, the Company had to assume the undertaking of their completion, looking to finishing the road within the time agreed upon, which naturally threw a large amount of additional work upon the Engineering Department. Added to these discouragements, it was difficult to secure men and teams, for aside from Louisiana being regarded a very unhealthy section—for other than natives —the large mileage of railroads then being constructed throughout Texas and adjoining States, gave more inviting fields to what labor there was in the market. The native labor was not attainable, due to its employment at the time upon the cotton crop. Contractors' supplies to the extent demanded could not be secured covering the western portion of the line.

Major Greene met these difficulties promptly and effectively. He immediately dispatched agents through the eastern southern States to secure about 1,000 colored laborers, who were at once sent to Louisiana and placed upon the work. He also sent agents to the western States and had collected at Shreveport a large and full line of contractors' supplies.

The road was divided into three divisions, viz: The New Orleans Division extending to the Atchafalaya River, the Alexandria Division from the Atchafalaya River to within 75 miles of Shreveport, and the Shreveport Division of 75 miles. Work was carried on over these three divisions at the same time, and engines, cars and track material having been delivered at Alexandria by Red River steamers, the track was laid from four ends. The ends of track were joined early in the spring of 1882. This road now constitutes the Louisiana Division of the Texas & Pacific Railway.

One of the important engineering accomplishments upon this line was the construction of the Atchafalaya River bridge. Much difficulty was encountered in securing the foundations, due to the heavy scour then taking place in the river, which at high stages of the Mississippi River, becomes practically the outlet to the Gulf of the Red River. The increasing cross section of the Atchafalaya River, occurring at that time, gave rise to grave fears on the part of many that if not controlled it would eventually carry the major flow of the Mississippi River.

Upon the completion of the New Orleans Pacific Railway, Major Greene tendered his resignation to accept the position of Chief Engineer of an extensive system of surveys for the Central Transit Railway Company, looking to the extension westward of the Cincinnati Southern Railway System, then constructing to Shreveport, Louisiana. His instructions were to secure the most feasible line from Shreveport, Louisiana, to a crossing of the Rio Grande River at a point about thirty miles southeast of Eagle Pass, Texas, where it was intended to connect with a Mexican railroad concession which would carry the line to Topolobampo Harbor on the Gulf of California.

His instructions limited him to a maximum grade of eight-tenths of one per cent and three degrees curvature. In view of the fact that all the principal roads in Texas at that time had maximum grades of one and one-fourth per cent, and that this line running in a general southwestwardly direction would have to cross the drainage of the whole State practically at right angles, the problem presented was not of the most encouraging character, looking to securing the desired ends within reasonable cost and without sacrificing the alignment.

Major Greene entered upon the work with his characteristic energy and thoroughness and soon placed three fully equipped corps in the field. The first profiles secured were very discouraging and the Major then took the field in person, spending much time with each corps, encouraging them to further effort and in examining new lines. His well directed labors were finally rewarded with success beyond his most sanguine expectations. Upon thirteen hundred and fifty miles of preliminary lines he effected a close approximate location of some six hundred and fifty miles, within the maximums to which he had been restricted and at a cost per mile below the average of that attaining upon the principal roads in Texas.

Not alone did he make the accomplishment of the engineering features of this undertaking his one ambition, but he evidenced an unselfish devotion to the cause by using his private means to finish the work thoroughly, and that after the Treasurer of the company had refused to honor his drafts, although being assured by the President of the company that he would be fully reimbursed upon the completion of the surveys—which promise however was never fulfilled.

His report, maps and profiles upon this work, submitted to the Central Transit Railway Company were most exhaustive and are monuments to his ability as a thorough and conscientious Engineer.

Baron Erlanger, a prominent banker of Europe had been made interested in this project and Major Greene had been selected by the home

company to present his report to Baron Erlanger in person, and was upon the eve of sailing for Europe upon that mission, when stopped by a cablegram, stating that a representative of the foreign interest would shortly arrive to look into the project here. The representative arrived but the fall in railroad securities at that time, 1883, finally resulted in the enterprise being laid aside until a more encouraging market should exist.

This was a great blow to the Major's ambitions as he had conceived the deepest interest in the project from its birth and had entered upon his portion of the work with his characteristic enthusiasm and determination. It, however, brought out fully those noble traits of his character, consideration for others and an intuitive sense of justice, for while this company continued to owe him a large amount for money expended on its account, he continued to pay off his corps, and largely with borrowed money, until his credit was exhausted, claiming that his assistants looked to him for their pay and that he would rather be reduced to penury than to have one of them say. that he lost a dollar through an engagement with him—even as the representative of a company.

During 1884 he undertook to revive the old Gulf and Ship Island railroad scheme. It is understood that he succeeded in having some location perfected, but aside from this, his efforts were not attended with the success he desired.

A pause now followed in railroad construction throughout the field of operations and foreseeing that there was no immediate prospect of its revival, he concluded, when his old collegemate and lifelong friend, Mr. Lamar, was apppointed Secretary of the Interior, to apply for a position in the young and new Northwest. Among the Territories Montana was his choice, and, as was entirely natural, he preferred the office of Surveyor General, since to that position he could bring the training and long experience of an active professional career. He was strongly endorsed for this office by the entire congressional delegation of his State and by the Presidents of the several railroad companies he had served in the capacity of Chief Engineer. Added to these endorsements, he was personally recommended to President Cleveland by Secretary Lamar, which resulted in his appointment, to take effect October the 29th, 1885.

He arrived in Helena, Montana, on December 4th, 1885, accompanied by his family. On leaving New Orleans the Press of that city were unanimous in expressions of regret at his departure and all joined in the hope that success might attend him in his new field of operations.

He filled the position of Surveyor General for Montana for four years with distinction and a conscientious regard for the public good. During this time he was requested to examine and advise upon several important engineering projects of both a public and private nature, which he always exhibited pleasure in doing—ever evidencing a keen interest in all enterprises affecting the profession to which he had devoted his life, and generously tendering his advice upon all public measures gratuitously.

Unknown to himself, family or friends, he had long been a sufferer from Bright's disease of the kidneys and during the last week of December

1889, he was attacked with a severe cold, which soon developed into an acute congestion of the kidneys, which, following Bright's disease, left the best of medical aid powerless to render assistance and all that could be done was to await the final moment. His bedside was surrounded by his loving wife and children and a few intimate friends and at five o'clock on the evening of the 4th of January, 1890, he peacefully passed away to the unknown beyond.

Major Greene left a family consisting, besides his wife, of three children —two daughters and one son.

He was a member of the American Society of Civil Engineers having joined that organization May 1st, 1878.

He was a charter member of the Montana Society of Civil Engineers and was the President of the Society at the time of his death, having been elected to that office January 19th, 1889.

Should we look for reasons why Major Greene was so universally esteemed and loved by all his assistants and why they exhibited at all times that true devotion to him and his cause, they can be readily found, not alone in the considerate impulses of his generous nature, but in that deep interest he ever deemed it a pleasure to take in the welfare and advancement of those who proved worthy of his consideration. His deportment towards his subordinates, whether Principal Assistant Engineers or laborers, was always accompanied with that gentlemanly bearing and delicate regard for the feelings of others, which was instinctive, evidencing true breeding and refinement and constituting a force governing his acts and bearings, which no influence, however strong, could prevent showing at the surface.

In closing our memoirs of Major Greene, we know of no more appropriate words than those of his life-long friend, Captain F. Y. Dabney, of Mississippi, who was his Principal Assistant Engineer upon several railroad enterprises and who says: "Benjamin H. Greene was not only a man of more than ordinary professional ability, but he combined all the graces of education and masculine refinement with an exalted sense of personal honor.

He was a typical embodiment of that chivalric spirit which in antebellum days characterized the "elite" of his native South—a spirit apparently incompatible with the mercenary tendency of the times and which, I regret to say, is fast disappearing as a distinctive feature of our section."

METHODS OF ASCERTAINING THE COST OF MANUFACTURES.

By Prof. C. H. Benjamin, Member Civil Engineers' Club of Cleveland.

[Abstract of Paper read January 13, 1891.]

I should hesitate to present this subject before a club of practical men, were my conclusions based on theory alone, unfortified by experience. I have had occasion in the past to use in a manufacturing establishment, a system of cost accounts similar to that oulined below, and was well satisfied with the results. Capt. Metcalfe of the Ordnance Department, U. S. A., has written a comprehensive work on this subject, outlining a system for use in U. S. arsenals, and to him I am indebted for much of the material for this paper. His system, as a whole, is too elaborate for most private shops, and needs abridgment. In the following notes an outline is given, a skeleton frame-work, to which details may be added as each may find desirable.

In keeping an account of work done in a shop, information must be had about three things: 1. Authority for work done. 2. Labor in doing the work. 3. Stock or material used. These must be treated separately; any attempt to show two or more on one piece of paper will result in confusion.

1. Authority.

Form A. Office order. This form is to be used when main office is at a distance from the shop, as when the office is in the city and the shop in the country, an unfortunate arrangement, but sometimes a necessary one. A press copy of this order is taken at the office, it is then sent to superintendent, and after the necessary entries are made in order book, it is filed by him as a voucher. A sheet of similar form, but with additional columns for journalizing, is filled out on completion of the work and returned to the main office, where it may be filed with others, forming a bill book.

Form B. Order Book. The orders are entered consecutively here and receive their shop numbers. This is about the only book used, and is a concise index of orders. An entry in the column "Finished" marks the completion of the orders.

Orders may be subdivided into: 1. Stock orders, so-called, for machine details in quantity. 2. Machine orders, for complete machines on special contracts. 3. Repair orders, for repair of machines brought in. 4. General orders, for work on tools, patterns, jigs, maintenance of shop and machinery, and in general, whatever cannot be charged to customers. Numbers from 1 to 100 should be reserved for general orders.

Form C. Order Cards. These should be of different colors for the

Form A.

SMITH MANUFACTURING CO.			
Date............		Office No...............	
Shipped............		Shop No...............	
A. B. JONES, Chicago, Ill.	One No. 2 Engine Lathe 20" complete with counter shaft		

Form B.

Date.	No.	Order.	Consignee.	Finished.	Remarks.

Form C.

SMITH M'F'G. CO.				Order No...............
MACHINE ORDER.				
Date............		Completed............		
For				
Details of Work				
Foreman punch here	1	2	3	4
Return to office.				

four different classes of orders. An order for setting up a machine may have the numbers of the parts printed on the back.

These cards are made out in duplicate, and go at once to foreman of room where work will begin. Each foreman should be provided with two display racks for cards; No. 1, for work awaiting attention and No. 2, for work under way. On receipt of order cards the foreman places them in rack No. 1, until he is ready to begin the work, when he gives one to the workman and puts the other in rack No. 2.

The workman should also have a smaller rack in which he can display all order cards which he has. By simply inspecting the various racks the superintendent is thus enabled to determine the exact status of all work in the shop. Each foreman should be provided with a common dating stamp, and with a ticket punch similar to those used by railway conductors.

When a workman has finished his work on a job, he returns the card to foreman, whence it passes to the next workman and so on. When all work is completed, the foreman stamps the date upon both cards, punches out his number upon them, returns one to office and retains the other as his record of work done.

When more than one workman at a time is employed on a job, the foreman may make out white duplicate order cards, which can be destroyed when work is completed. Sometimes foreman may make sketches on cards, to assist in explanation of the work, but this should be avoided, as all work should be done from carefully executed detail drawings.

When the order card is received at the office, the date of completion is entered in the order book and the card filed away.

Advantages of Order Cards: They show the progress of the work at any time; are evidence of authority to both foreman and workman; they disappear when work is done and leave the coast clear for others.

2. Labor.

Form D. Time Card. This card may be of sufficient size to contain all the orders worked on during one day, but when practicable it is better to have but one entry on each card, thus making it a unit. The cards may be bound in book form, with stubs like a check-book on which workman can preserve a record for his own satisfaction.

Each workman receives his time-book from foreman on beginning work for the day, and returns it filled out, one leaf for each order, whenever he quits work. If workman is illiterate, the foreman may enter number of order and kind of work when he gives workman the book, leaving simply the number of hours to be entered by workman. Each night the foreman takes all the time-books, stamps date on cards, punches them in proper place, tears them out and sends them to office.

The name, shop number and wages of workman are written, stamped, or printed on each leaf of book before he gets it, so that he has no more writing to do than in any system.

Absence, of whatever duration, is noted by the foreman on leaf of time book, and this card is dated, punched and sent to the office with the

Form D.

SMITH M'F'G. CO. Date..................

TIME CARD.

No. 124. Robert Jones. 25c per hour.

Order No.	Kind of Work.	Hrs.

Form E.

FRONT.

SMITH MFG. CO. Order No.______

STOCK CARD.

Date..................

No.	Units.	Material.	Price.	Amounts.
			Total	

Issued by Rec'd by

BACK.

No. Pieces.	Material.	Dimensions.

others, forming positive evidence of the absence, instead of merely negative.

Piece Work. If workman is paid by the piece, the word "piece" in red ink may be stamped over hour, and the amounts not filled in until the work is completed. The leaves or coupons in the book may be serially numbered to prevent fraud.

Route of Time Cards. These cards, as has been seen, go daily from foreman to time clerk, who posts time to a book and stamps "Posted" on cards. He passes them on to cost clerk, who shuffles them according to numbers of orders, and places them in pigeon-holes temporarily labeled with such numbers. Each pigeon-hole thus shows how much labor has been expended on that order to the night preceding.

Advantages of Unit Time Cards. 1. The workman charges for his labor *himself,—at the time*, and *but once*. 2. This original entry is made the basis both of wages paid and of cost charged.

3. Stock or Material.

This term includes both rough material, such as castings and forgings, and also finished parts from the store-room.

Form E. Stock Card. The requisiton for stock may be on the back of card, or separate, as thought best. It is here shown as printed on back of stock card.

The requisition is made out by foreman; he then writes number of order on face of card, stamps date and punches after "Received by." The card then goes to stock-room where the stock is counted or weighed out by the stock clerk, who enters details on face of card, punches after "Issued by," and retains card as a receipt. He then posts stock to stock journal, stamps "Posted" on card and sends it to the cost clerk who files it the same as time cards.

All stock returned as defective or superfluous is entered by foreman on similar card of a different color, "Issued by" is punched by foreman, "Received by" punched by stock clerk, and the card sent to cost clerk with the others.

When foreman or inspector turns in spare parts to store-room, he fills out a return stock card and has it receipted by clerk. The clerk in charge should refuse to receive parts, unless accompanied by such cards, as a guarantee of the parts being all right.

Form F. Stock Ledger Card. A stock account must be kept in the casting store-room, in the stock-room for bar iron, steel, etc., and in the spare part room for finished work. The same general system applies to all. The stock journal is simply a Dr. and Cr. account of the cost of all stock turned in and issued. A balance at any time will show the cash value of stock on hand. If a separate account with each kind of stock is desired, the ledger cards, Form F, may be used, one card for each kind.

In the spare part room the card would be the same, save that symbol of piece and piece cost would be substituted for kind and price. Each card would begin with the amount on hand when card was started, and balance would be corrected each time account of stock was taken. The

Form F.

STOCK ROOM.

Kind .... Price ....

Date.	Order No.	Remarks.	Dr.	Cr.

Form G.

SMITH MANUFACTURING CO.

No. .... Name .... Rate .... per hour.

Shop .... Occupation ....

Date.	Order No.	M.	T.	W.	T.	F.	S	Total.	Rate.	Amount.

Form H.

SMITH MANUFACTURING CO.

Daily Cost Sheet. Date..

No. of Order.	Labor.		Expense	Stock.	Gross Cost.	Credit.	Net Cost.	Bro't. Forw'd.	Total to Date.	Remarks.
	Hours.	$	$	$						

Form I.

C. S. A. S. Order No.......................................

COST CARD.

Date...

NAME.	WOOD SHOP.		IRON SHOP.					Rate.	Cost.
	Bench.	Lathe.	Forge.	Planer.	Miller.	Lathe.	Bench.		

	RUNNING EXPENSE.		
Piece Cost.	Stock.	Quantity	Price

only sure way to determine the actual number of pieces of any kind on hand, is to go to the box, drawer or rack and *count* them. These cards are to be filed on an ordinary letter file.

Form G. Time Book. This book is only used for settling with men. The time is posted daily from the time cards. One complete page is used for each man.

Form H. Daily Cost Sheet. If it is desired each day to know the cost up to the night before of any work under way, the cost clerk can post from time and stock cards to this sheet. Each day a fresh sheet is made out and the old one destroyed.

Form I. Cost Card. When a job is done and all time and stock accounted for, the latter are posted to a permanent cost card which is filed for future reference. The card explains itself. The subdivision of labor may be carried to any desired extent. The "Running Expense" is added in at the most convenient place, as it is usually either a percentage on the cost of labor or a rate per hour for all time charged. The piece cost should be figured out in the lower left corner, and posted to a condensed cost book, having one page for each piece, where the successive costs can be entered and a comparison readily made. These cost cards are to be filed permanently in racks, bearing the numbers or symbols of the pieces, and easily accessible.

In summing up I would say that in my opinion any system, to be successful, must depend on an extensive use of cards instead of books, and an equally extensive use of printer's ink instead of writing. The workman must have little or no writing to do, save putting down his time, and the foreman should be relieved from clerical work by the use of stamps and punches, and still have direct supervision of all time and stock cards, none of which should be valid without his stamp.

One of the chief advantages of a rigid scrutiny of costs is the effect upon the men since they know that their relative value is understood at the office.

A cost card like the sample given enables the superintendent to spot at once the cause of unusual cost in a piece or lot, and determines who is to blame.

A firm manufacturing standard machines year after year with little change can employ such a system with much less expense than one which has much contract work of a varied nature. I have used such a system in a shop where the work was of both kinds, and a sharp line had to be drawn between stock orders and machine orders.

Each manufacturer must decide for himself how far it will pay him to carry a system of cost accounts, but must insist on having what is done, done thoroughly and well, as less than this means time and money thrown away.

DISCUSSION.

MR. SWASEY:—I will say to you gentlemen that have perhaps all of your lives had nothing to do directly with manufacturing, you may think there is a good deal of detail to this, but if you manufacture a great while you will finally get somewhere near this. There are different ways of accomplishing this same thing, but of course it has to be modified and adapted to a business. No longer ago than to-day one of the largest concerns in the East, that you all know (I will not mention any names, because I know they would not want to have me do so), knowing that we had had some experience in this cost system, sent us a letter, asking that we send them duplicate time cards and all of our cost and time system, for they had found out after several years of manufacturing that they did not know anything about what their machinery cost them. I know I am saying a good deal, for I am speaking of a large and prosperous concern that you all know about, but they have been jumping at conclusions and they have happened to jump on the right side, but they are just waking up and finding that they must know what their machinery costs them. That is the trouble with a great many manufacturing concerns and when they come around to the end of the year the stockholders think there are not very large dividends, but the superintendent does not know what his work is costing him and therefore he can not regulate the price.

MR. BARBER:—I have been using the card system to a limited extent and I think after hearing this paper I shall use it somewhat more. I think as Mr. Benjamin does, that printers' ink in a factory is a good investment, and I have been acting on that principle and find it of great benefit in every case. In my work a great many of the cards that I print are largely for the purpose simply of information and some of them are not so much as to cost, but simply as to information. We have a large amount of work going on where great care is necessary in the management of different parts of the work, and sometimes whether the work has gone on properly or not is not known for several days afterward, and by having a record of the work as it was done—just as it was done—it can be conveniently referred to at a later date when it is found that something may have gone wrong or when it is found that results have been reached that were not expected.

MR. HERMAN:—I will say on this subject that the whole system is very complete as it is presented here and I will only take exception to one remark that Prof. Benjamin has made in regard to destroying such cards. Any record that has been obtained ought to be retained. Three times Prof. Benjamin mentioned that these cards may be destroyed. I would make serious objection to that in any system. After any thing has been once put down it should be kept. While you might not use it once in a hundred times, there might come a time when you would want that very piece of paper you have destroyed.

PROF. BENJAMIN:—I should be in favor of preserving all records myself. The only reason why I spoke of destroying any of these cards was that I thought perhaps that was the only thing that would reconcile a great

many people to use them, but I think myself that all cards ought to be retained. There is one thing I did not emphasize and that is the running expense.

It is the difference between success and failure in a great many shops and I would like to hear from any one who has had any experience in that direction. I am considerably interested in it myself.

Mr. Herman:—I may give in the experience of a firm that kept a general expense account throughout the year and divided that by the amount of business done throughout the year and got the percentage which was added in the estimate book after the estimate for the shop was figured out, then they added a certain percentage for general expense. This percentage was changed from year to year and it was always based on the amount of business done the year before. It was a very crude way and a very misleading one.

TRANSIT IN LONDON, RAPID AND OTHERWISE.

By James A. Tilden, Member, Boston Society of Civil Engineers.

[Read April 2, 1890.]

The methods of handling the travel and traffic in the city of London form a very interesting subject for the study of the engineer. The problem of rapid transit and transportation for a city of five millions of inhabitants is naturally very complicated, and a very difficult one to solve satisfactorily.

The subject may be discussed under two divisions: first, how the suburban travel is accommodated, that is, the great mass of people who come into the business section of the city every morning and leave at night; second, how the strictly local traffic from one point to another is provided for. Under the first division it will be noted in advance that London is well provided with suburban railroad accommodation upon the through lines radiating in every direction from the centre of the city, but the terminal stations of these roads, as a rule, do not penetrate far enough into the heart of the city to provide for the suburban travel without some additional methods of conveyance.

The underground railroad system is intended to relieve the traffic upon the main thoroughfares, affording a rapid method of transportation between the residential and business portions, and in addition to form a communicating link between the terminals of the roads referred to. These terminal stations are arranged in the form of an irregular ellipse and are eleven in number. If you will take the city of Boston as a model on a small scale of the city of London, you will observe that the stations are arranged in a somewhat similar way, that is, on an irregular ellipse, and are eight in number.

One of the most noticeable features of the underground system in London is that it connects these stations by means of a continuous circuit, or "circle," as it is there called. It bears the same relation to the stations, in point of convenience, as if a circuit line were run in Boston connecting the several stations. Still another coincidence: the larger diameter of the "circle" is traversed by two main thoroughfares which correspond very closely to Tremont and Washington streets. They are respectively, Oxford street, Holborn and Cheapside for one thoroughfare, and Picadilly, The Strand and Fleet street for the other.

To carry out the coincidence still further, if a map of Boston were laid over one of London on a scale relative to the sizes, so that the "circles" formed by the stations would coincide, the Bank of England would be found in the vicinity of State street, and the large retail stores of Oxford street in the vicinity of Washington and West streets. It will be borne in mind in making this comparison that the larger diameter of the "circle" in London is about five miles, and the smaller two miles, where in Boston the distance would not exceed a mile and a half in any direction. The character of travel in the two cities is very much the same, extremely crowded in the morning by the inflow of persons going to business, and very crowded at night in the other direction by the outflow.

Now by reference to the map exhibited, it will be seen that the heavy red line connecting the terminal stations represents what is called the "inner circle." There is also an extension at one end of this elliptical shaped circle which also makes a complete circuit, and which is called the "middle circle," and a very much larger circle reaching the northern portions of the city, which is called the "outer circle." The eastern ends of these three circles run for a considerable distance on the same track. In addition to this the road branches off in a number of directions reaching those parts of the city which were not before accommodated by the surface roads, or more properly the elevated or depressed roads, as there are no grade crossings.

With regard to the accommodation afforded by this system: it is a convenience for the residents of the western and southern parts of London, especially where they arrive in the city at any of the terminal stations on the line of the "circle," as they can change to the underground. They can then reach the eastern end of the "circle," at which place is located the bank and the financial section of London, in a comparatively short time. For example, passengers arriving at Charing Cross, Victoria or Paddington stations, can change to the underground, and in ten, fifteen and thirty minutes respectively, reach the Mansion House or Cannon Street Stations, which are the nearest to the Bank of England. In a similar manner those arriving at Euston, St. Pancras or Kings Cross, on the northern side of the "circle," can reach Broad Street Station in ten or fifteen minutes, which station is nearest the bank on that side of the "circle."

In a number of cases the underground station is in the same building or directly connected by passages with the terminal stations of the roads

leading into the city. Examples of this kind would be such stations as Cannon Street. Victoria or Paddington. They are not, however, sufficiently convenient to allow the transference of baggage so as to accommodate through passengers desiring to make connection from one station to another across the city. Hand baggage only is carried, about the same as it is on the elevated road in New York. The method of cross town transfer, passengers and baggage, is invariably done by small omnibuses, which all the railroads maintain on hand for that special purpose.[a] A very large proportion of the travel, however, if not the largest, is obtained by direct communication by means of the "circle" or branch lines with the various residential portions of north, west and south London.

Before proceeding with the details of construction and management of the underground roads, a brief sketch of other methods of transportation will be given. The two principal methods, which reach out well into the suburbs, are the omnibuses, and the tram cars, which is "English you know" for horse cars. The tram car lines, with one or two exceptions, do not penetrate within the "inner circle" of the underground railroad, and consequently are no more conveniently located with reference to the centers than the terminal stations of the through lines. The reason for this is that the streets are so narrow and crowded that it would be impossible to accommodate them. Some of the main thoroughfares upon which there is the greatest amount of travel are no wider than Washington street in front of the newspaper offices. It may be observed that wherever the word "accommodated" is used in this paper with reference to a certain *relative* convenience afforded by the methods of transportation described, it oftentimes means "not accommodated."

To facilitate the travel a great many of the streets are covered with asphalt or wood pavements so that as a general thing the omnibuses ride as easily as the tram cars. The omnibuses carry twenty-six passengers, fourteen outside and twelve inside, and no person is allowed to get on unless there is a vacant seat. This same rule also applies to the tram cars. The after-theatre traveler in Boston has often wished that this ideal state of affairs might prevail here. What becomes of those who are unable to find a seat in a tram car or omnibus does not appear, but it is thought that they either wait, or take a cab, or walk.

It is the special duty of the police to regulate the passage of vehicles, inclusive of omnibuses and cabs, keeping them strictly in line in the narrow streets, and to the left instead of to the right, as is the custom here. In this manner blocks are almost altogether avoided, although delays are the rule, all vehicles being kept on their side of the street as rigidly as if they ran on rails.

The tram cars are somewhat longer than those in use here, and will accommodate as many people outside as inside. To both omnibuses and tram cars are affixed stairs which afford easy access, even for ladies, to the top. In London, and generally throughout England and the continent, the grooved flush rail is used, which does not in the slightest degree obstruct the passage of vehicles, and is certainly a very valuable improvement over the rail in use here.

A large number of passengers are accommodated by the main stations of the through railways which come into the city, and which are centrally located, without the necessity of transfering to any other mode of conveyance. Reference is had to Charing Cross, Holborn, Cannon St., Fenchurch Street and Liverpool Street Stations.

Finally, there are several lines of boats on the river which touch at frequent landings, and at convenient and central points, running at few minute intervals, which also convey a large number of passengers and make very good time.

The strictly local traffic which was distinguished from the suburban in the first part of this paper, is provided for by the omnibuses, the underground railroad, the main lines and tram cars, and in point of convenience about in the order named. By far the most convenient method of local rapid transit in use is the cab system, as it is found there in its highest development. The number of cabs, which is something more than twelve thousand, furnishes a ready mode of conveyance and is conducted on such a perfect system as to really be a wonderful convenience. In fact, seventy-five per cent. for a rough estimate, of the vehicles on a London thoroughfare are cabs and omnibuses. The cabs are so numerous that one can be hailed at almost any time of the day or night, or on any street. The Hansom cab is by far the most common and comfortable, although there is a generous proportion of "four-wheelers," or coupes. The rates of fare are very low, only one shilling (twenty-five cents) for two persons for two miles; sixpence (12½ cents) for each additional mile. The rate is no more for two persons than one, and a sixpence is charged for each passenger more than two. By the hour, two shillings and sixpence is charged.

Approximately on the underground railroad the fare is one cent per mile for third-class, one cent and a half for second-class, and two cents for first-class, but no fare is less than a penny, or two cents. Omnibus fares in some instances are as low as a penny for two miles. This is not by any means the rule, and is only to be found on competing lines. The average fare would be a penny a mile or more.

The fares on the main lines which accommodate the suburban traffic are somewhat higher than on the underground, perhaps fifty per cent. more. In every case, on omnibus, tram cars or railroads, the rates are charged according to distance. The system such as is in use on our electric, cable and horse cars, and on the elevated road in New York, of charging a fixed fare, is not in use anywhere.

Proceeding now to the details of construction of the underground roads: the ticket office is generally on a level with the street. In some instances both the up-town and down-town trains are approached from one entrance, but generally there is an entrance at either side of the railroad, similar to the elevated railroad system. In purchasing a ticket, the destination, number of the class, and whether it is a single or return ticket has to be given. The passenger then descends by generally well-lighted stairways to the station below, and his ticket is punched by the man at the gate. He then has to be careful about two things: first, to place himself

on that part of the platform where the particular class which he wishes to take stops, and secondly, to get onto the right train.

In the formation of the train the first-class coaches are placed in the center, the second and third-class respectively at the front and rear end. There are signs which indicate where the passengers are to wait according to the class. There is a sign at the front end of the engine, which to those initiated sufficiently indicates the destination of the train. The trains are also called out, and at some stations there is an obscure indicator which also gives the desired information.

The stations are from imperfectly to well lighted, generally from daylight which sifts down from the smoky London atmosphere through the openings above.

The length of the train averages about eight carriages of four compartments, each compartment holding ten persons, making a crraying capacity of three hundred and twenty passengers. The equipment of the cars is very inferior. The first-class compartments are upholstered and cushioned in blue cloth, the second-class in a cheaper quality, while most of the third-class compartments have absolutely nothing in the way of a cushion or covering either on the seat or back, and are little better than cattle pens. The width of the compartment is so narrow that the feet can easily be placed on the opposite seat, that is, a very little greater distance than would be afforded by turning two of our seats face to face. The length of the compartment, which is the width of the car, is about a foot and a half less than the width of our passengers cars, about equal to our freight cars. Each compartment is so imperfectly lighted by a single lamp put into position through the top of the car, that it is almost impossible to read.

The length of time which a train remains at a station is from thirty to forty seconds, or from three to four times the length of time employed at the New York elevated railroad stations. The reason for this is that a large proportion of the doors are opened by passengers getting in or out, and all these have to be shut by the station porter or guard of the train before the train can start. If the train is crowded one has to run up and down to find a compartment with a vacant seat, and also hunt for his class, and as each class is divided into smoking and non-smoking compartments, making practically six classes, it will be observed that all this takes time, especially when you add the lost time at the ticket office and gate.

The ventilation of the tunnels and even the stations is oftentimes simply abominable, and although the roads are heavily patronized, there is a great amount of grumbling and disfavor on this account. The platforms of the stations are flush with those of the cars, so that the delay of getting in or out is very small, but the doors are so low that a person above the average height has to stoop to get in, and cannot much more than stand upright with a tall hat on when he is once in the car. The monitor roof is unknown.

The trains move with fair speed, and the stations are plainly and liberally marked, so that the passenger has little difficulty in knowing when to

get out. There are two signs in general use on English railroads which are very simple and right to the point, namely, "Way Out" and "Way In," so that when a passenger arrives at a station he has no question how to get out of it. The ticket is given up as the passenger leaves the station. There is nothing to prevent a passenger with a third-class ticket getting into a first-class compartment, excepting the ominous warning of forty shilling fine if he does so, and the liability of having his sweet dreams interrupted by an occasional inspector who asks to see the denomination of his ticket. All compartments intended for the use of smokers are plainly marked and are to be found in each class.

Almost the entire part of the railroads within the thickly settled portions of the City run in closed tunnels. Outside of this they frequently run in open cuttings, and still further out they run onto elevated tracks.

With regard to the equipment of the suburban or surface lines not belonging to the underground system, the description is about the same. The cars are generally four compartments long and sometimes not exceeding three. They are coupled together with a pair of links, and fastened to the draw-bar on one car, and the other thrown over a hook opposite, and brought into tension by a right and left hand screw between the links. This is obviously very inconvenient for shunting purposes, especially as the cars are not provided with hand brakes, and no chance to get at them if there were any. Consequently it appears that when a train is made up it stays so for an indefinite period. A load of passengers is brought into the station and the train remains in position until it is ready to go out. As the trains run very frequently this appears to be a very economical arrangement as no shunting tracks are needed for storage.

The engine which brings the train in of course cannot get out until the train goes out with the next load. Turn-tables for the locomotives are but very little used as they run as double-enders for suburban purposes.

In conclusion, it will be safe to say that the problem of rapid transit for a city as large as London is far from solved by the methods described. Although there are a great many miles of underground lines and main lines, as they have been called throughout the paper, and although grade crossings have been entirely abolished, allowing the trains to run at the greatest speed suitable to their frequency, still there are a great many sections which have to depend entirely upon the omnibus or tram car.

The enormous expense entailed by the construction of the elevated structures can hardly be imagined. We have but one similar structure in this country, which is that running from the Schuykill River to Broad Street Station in Philadelphia. Those who have seen that excellent piece of work can form some idea by comparing its length with the mileage indicated by the blue lines on the map exhibited. The underground system is even more expensive, especially in view of the tremendous outlay for damages. This goes to show that money has not been spared to obtain rapid transit.

After all, the means to be depended upon when one desires to make a rapid trip from one part of the City to another, is the really admirable,

cheap, always ready, convenient and comfortable London hansom; while the way to see London is from the top of an omnibus, the most enjoyable if not the most expeditious means of conveyance.

DISCUSSION.

Mr. H. D. Woods:—In answer to Mr. Tilden's request for a description of the circular railroad around Paris, I would state that this road is especially designed to facilitate travel between the outer districts of the ciry, rather than to give rapid transit, in the city proper. I should state, however, that the habits and the distribution of the population of Paris are quite different from what we find here. There is no one special district where all the business community is collected during the day-time, which is abandoned to darkness and solitude at night. The city has grown out in concentric circles, so to speak. The further out you get, in most directions, the lower rents become, as they do here, but still there remains in almost every street dwellings in the form of apartment houses, even in the centre of the business quarters.

Although retail stores of all descriptions can be found in every district, there are separate districts for almost every different branch of trade. Thus the dry goods houses (wholesale) are nearly all located near the center of the city, and the Bank. The crockery and glassware people are on the other side of the boulevards. The furniture manufacturers are all in the Quartier Saint Antoine, at the east end of the city. The hide and leather people are over on the left side of the river, at the extreme south of the city; the sugar refineries, all at the north. The machine shops are mostly at Grenelle at the southeast, and at the north towards Clichy and St-Ouen. For this reason, there is a daily distribution of the population in almost all directions, as the mass of the people live near the outskirts of the city.

The *Chemin de fer de Ceinture*, which encircles the city just inside of the fortifications, has a length of 37 km. or about 23 miles. The line starts from the station of the Western Railroad on the right bank of the river, and starting out towards the fortifications, turns to the left and continues around, crosses the river twice, and connects with itself again, near the fortifications by a switch. There is no train that, starting from the western station, returns to it. Passengers have to change at the switch. This is done to obviate all grade crossings. Trains run in both directions at fifteen minute intervals, so that any one wishing to go from the western station towards the right, goes out to the switch, and changes trains.

This road connects with all the railroads entering the city, eight in number. There are grade connections for freight purposes, but all passenger trains pass either over or under the other lines, and passengers have to make a change if they wish to connect with the other roads. Owing to the topography of the ground, the Belt road is partly under ground and partly on a viaduct. Soon after the start it enters a deep cut, which continues for four miles, when it reaches the surface at Passy, and rises to

a long stone viaduct about two miles long, the arches of which are pierced so as to make a covered walk for foot passengers, with a wide drive-way on each side. The road crosses the river on this viaduct, with carriage-ways below. After a short embankment the road enters a short tunnel near the Left Bank Station of the Western R. R., then an open cut, and a tunnel through the Catacombs and the public park of Montsouris and below the Sceaux R. R. The road continues a short distance in a cut, then appears on the surface, crosses the river, then the Vincennes, and Lyons Railroads on a viaduct, but soon gets into a cut again, and a tunnel under Pere Lachaise Cemetery, then another tunnel under the park of the Buttes Chaumont. These last two tunnels are some distance inside of the fortifications and the road gradually runs out again till it nears the fortifications. A branch runs out here to the city slaughter houses and cattle market. Thence the road continues, crossing the Eastern and Northern roads on bridges, then along the surface for a short distance, then crosses below the Western Road, and connects with itself again in a cut.

The road is administered by a railroad syndicate, formed by a combination of the roads entering the city. In 1884 this road carried an average of about 45,000 passengers per day. These were either passing through the western station into or out of the city, or going on the circle. At the same time the different lines of omnibuses, tramways and steamboats and the street hacks were carrying some 1,100,000 per day, inside the circle mostly.

For over fifteen years the question of a metropolitan road has been agitated in Paris, and numerous projects have been advanced and companies formed to carry them out, but as yet nothing has been accomplished in this line. One great difficulty there, is that one single line cannot answer the purpose; there must be a network of lines, on account of the various directions that have got to be served. A cross town road would be of very little practical value there.

The eight railroads that enter the city all have their stations about a mile and a half inside of the fortifications; which brings them about the same distance from the geographical center of the city. Two of them come in on an elevated road. The Vincennes Railroad inside the fortifications is built on a brick and stone viaduct nearly two miles long, the arches of which are used for stores, workshops and dwellings, being high enough for two stories.

ON THE ADVANCEMENT OF THE PROFESSION OF THE CIVIL ENGINEER.

ANNUAL ADDRESS OF CLEMENS HERSCHEL, PRESIDENT BOSTON SOCIETY OF CIVIL ENGINEERS.

[Delivered March 18, 1891.]

It is provided in the constitution of many Engineering and other Scientific Societies, that tne President shall deliver an annual address; some of these bodies ot the fundamental law also prescribing the subject matter of the address to be presented.

Our own society has no such provisions in its constitution; and it thus remains optional with the President, what manner of address he will deliver; or, indeed, whether he will deliver any. But the custom has grown up that the President, by the delivery of an annual address, may fitly show his appreciation of the honorable office his fellow members have conferred upon him—a custom which I gladly follow. And as the subject matter has thus been left entirely free to the choice of the President, I take the occasion to select one, which is very dear to me—the advancement of the profession of the civil engineer—more especially in this country.

We are met at the very beginning of our consideration of this subject by the question, whether it has been rightly named; is the civil engineer a member of any of the learned professions; or does he not rather follow a trade, or perhaps a calling, of a somewhat lower ethical standard than those ordinarily called professions. And it may be instructive in this connection to endeavor to define just what constitutes a profession, and what, a trade or occupation; these words being taken in their current meaning.

This is a branch of the subject upon which I have often pondered, until the difference between the two things named has at last become clear to me; as so often happens, by looking at them from their sentimental or spiritual side only. My conclusion has been, that the difference between a trade and a profession, is gauged by the amount of confidence voluntarily reposed, or deposed, for the time being, by the employer, in the employed. The conduct of mankind in its dealings with the employed, gives those employees their standing; whether as men of a certain profession, or as following only a certain trade; and the touch-stone of such conduct, is the amount of confidence that is voluntarily given by the one to the other.

No lawyer is an honored member of an honorable profession, who does not spontaneously command, and as spontaneously receive, the entire, the closest confidence of his clients. Observe how quickly men practicing at law, change from members of a profession, to men passing by various opprobrious epithets; and to mere parasites upon society, so soon as men do not freely give them their whole confidence. The confidence given must be given spontaneously and cannot be solicited. If not received spon-

taneously, it cannot be otherwise procured; and from failing to receive that of his clients, such so-called lawyers soon fail to receive that of any members of the community, and become members of anything but a profession.

Can anyone imagine a member of the medical profession, except he be given the confidence of his patients? I presume the only reason why veterinary surgeons, whether of a Royal College, or of a lower educational standard, and—they will pardon the conjunction—why even dentists have such up-hill work in being considered members of a profession, is that their duties call for so limited an amount of the confidence of their clients to be placed in them. The more valuable the work done by them, the more confidence reposed in them prior to that work, the more they too will be considered members of certain branches of the medical profession. Doctors finally, who go about soliciting the confidence of their fellow men speedily become quacks.

Ministers of the gospel and heads of other religious bodies, naturally receive the full confidence, in certain directions, of their parishoners, and by that act, become members of a profession. If this confidence be not given them spontaneously, then they too cannot, to such as do not give them this their entire confidence, appear as members of any of the learned professions. So that it may be said, that by reason of the amount of confidence evoked from their fellow men, throughout the centuries that have passed, these three, law, medicine and theology, have been considered the three learned professions; and in a measure, it remains to be seen, whether in these United States of America, these three can or cannot retain a monopoly of that appellation.

This difference between the professional employee and the hireling, between the "friend," and the "servant," as it is there written, may be found laid down in Scripture. "For the servant knoweth not what his lord doeth." A servant is told to do a certain thing, and does it, not being consulted as to, knowing, or caring for, the reason why,—and is a servant; while the friend, or member of a profession, has given him his employer's confidence, is consulted on every phase of the subject matter, and himself carries the responsibilities of the situation to the fullest extent.

I think I have illustrated my argument sufficiently to make clear, that in the measure that civil engineers will have given them the confidence of their employers, they will act as members of a profession, or else of a trade or calling.

The advancement of the profession of the civil engineer in this country, is then a difficult thing to accomplish by the designed efforts of men. As in many another social question, causes and effect re-act upon each other, and the education of a whole community is necessary, for the purpose held in view. In certain of the European countries, civil engineers have always been placed in positions of palpably greater responsibilities than is the rule in the United States, and I doubt if the question of their being members of one of the learned professions could there have ever been properly raised.

We have the statement of the President of the American Society of

Civil Engineers, to the effect, that he is anxious to see raised to a still higher plane, the position that engineers take in this country; "which," says he, "in my judgment, is as yet inferior to the position they hold abroad, and the position which I feel sure they will attain in the future.

One of the pleasantest features of the trip of the American engineers to Europe was in observing the respect, the honor with which engineers are treated abroad. Not only do they receive very much better compensation than in this country, but they are looked upon as at the head of the industrial movements, and without whose assistance no great scheme can be carried out. Among the first visits which we paid while in London, was one to Westminster Abbey, and there we found monuments to engineers by the side of the great warriors and statesmen that that country has produced. In the picture galleries the pictures of engineers were hanging upon the walls. We find long aisles in the Crystal Palace filled with busts of these engineers.

When the fact was known that we were American engineers, the doors of welcome were opened wide to us all through Great Britain, and when we arrived in France we found that a civil engineer was one of the ministers of state and another the president of the French Republic. When he met the American engineers he told them that he received them, not only as Americans but as his comrades, and the mere fact that they belonged to that profession was a passport to them, not only to all the places of interest which they wanted to visit, but also to all social entertainments, and they came away—the whole 300 who paid that visit last year—came away with the most gratifying impression of the high social position which our profession occupied abroad, and with the hope that by strong efforts to raise the standard in this country, a similar recognition might be obtained here."

To this, all who are acquainted with the life of the profession anywhere in Europe can bear concurrent testimony.

The accomplished Mayor of Geneva, Switzerland, is a civil engineer elected as such, after having completed a notable engineering work fo his native city; and for the design of the Liverpool water works, an honored member of the profession is reported to have recovered in the courts over $100,000, not long ago, upon his not being retained in charge of the work thus begun by him.

Although these are merely straws that show which way the wind blows, I do not remember to have read the like items in the newspapers, in which the scene was laid in the United States.

The position in the body politic, and in the community, of the civil engineer on the continent of Europe, is something that must be seen and felt on the spot in order to be thoroughly appreciated. He is there a marked member of the community, having distinct functions and duties. Where we appoint committees of butterfly existence to report, or even to execute engineering works, a French or German township, or county or state, will act as would a well organized American city, having a city engineers' department; or better still, a board of public works; or will appoint a committee consisting of engineers only. Those of our citizens who go abroad,

come back delighted with the results of the well regulated systems of carrying on the public works which they see; as for example, magnificent bridges, perfect roads, a *general* impression of neatness, order and good work; but the engineers of this country have done fully as well, whenever they have been given opportunity. And it is plain, that to reproduce the appearance in this country of the engineering works, which these gentlemen find so delightful abroad, they have but to consider, that like causes produce like effects; and give opportunity at home to an equal extent to the followers of that art which builds these works.

In defining what constitutes the profession of a civil engineer, we probably, will never improve on those grand words of the charter of the Institution of Civil Engineers, of Great Britain, which speak of it as "being the art of directing the great sources of power in Nature for the use and convenience of man." It may be but natural, that so wide a domain should with difficulty be kept free from the encroachment of all sorts and conditions of men, other than civil engineers. This seems to be especially true in England, the parent country, and its colonies; and in the United States, its offspring. The politician, the lawyer, the teacher of youth, the military engineer, savants of various degrees of childlike simplicity and of impracticability, the citizen at large, the old-time driver of a four-horse stage coach, all pose, from time to time, in the eyes of the public, as practicing civil engineers; and proceed, improperly to direct the labors of the civil engineer. Hovering about the profession, yet not of it, are contractors, promotors, and other such seekers of mammon first, and of "the art of directing the great sources of power in Nature for the use and convenience of man," afterwards; while closely connected with the profession and yet not in itself constituting it, are land and hydrographic surveyors, map makers and the like. After such a review of the situation let us not despair. There is after all, or is to be, the profession of the civil engineer; and other professions have too, their poachers and their quacks. Take for instance the medical profession, and observe its enemies and parasites as such.

Not to mention grandmotherly remedial agencies, consider the great army of patent medicine compounders and vendors; quacks of every name and nature, from the faith-healers of the cities, to the four white horse and brass band charlatan of the country towns; think of the great army of apothecaries, even yet sometimes individually called doctors, and take courage in the fact that there is nevertheless a medical profession. The parallel between apothecaries and surveyors, has always seemed to me a neglected point of knowledge to the general public. Stated in arithmetical language, we might put it, that, as apothecary is to doctor, so is surveyor to civil engineer. A doctor must know the apothecary's art, as the engineer must know all about surveying; but neither need especially practice his respective subordinate calling; and the general public should be taught to recognize the difference between the two. It is for the reasons here touched upon, because the difference between surveying and civil engineering was slurred over, instead of having been accentuated, as it should have been, that many engineers in the United States have always

deeply regretted the choice of badge made by the Am. Soc. C. E.; which is a levelling instrument, on a blue field. Rather than to confirm the general public in its notions of the equality of the two occupations, it should have been taught their difference, on an occasion like this. Instead of placing on its badge "something of the earth, earthy," the badge should have borne a conventional figure, typical of the whole art of the civil engineer. Had the levelling instrument been of a bye-gone age, it might have figured as appropriately on the badge of the Am. Soc. C. E., as do the crossed hammers on the badge of the Am. Inst. of Mining Engineers; but under existing circumstances, the choice made, originally at the instance of an ordnance officer of the United States Army, can hardly be said to have contributed to the advancement of the profession of the civil engineer, "being the art of directing the great sources of Nature, for the use and convenience of Man."

We have seen something of the position of the civil engineer in communities living under minutely regulated forms of government, such as France, Germany, and other continental countries. That our own present status is but a forerunner of the same general standing of the engineer in the United States, many signs seem to indicate. Time was, not so very long ago, when there could hardly be said to have been such a thing as an architect abroad in the land. Most of us remember the modest signs, "architect and builder," following those of "carpenter and builder," or of "mason and builder;" and only recently followed by those of "Architect." Time was, not so very long ago, when cities had no city engineer; only a city, or, possibly only a county surveyor; or no official representative of the engineering profession whatever among their officers. Such is the condition of affairs in counties, in states and in the United States, even now. Yet there can be no good reasons cited why the execution and the care of the public works of the county, of the State, and of the body of States, should be in any more heterogeneous condition than is that of the cities, and there are signs that seem to indicate the coming change. Thus, counties and States are agitating the subject of better road-making, and with consideration of the subject comes the conviction that to have a thing well done it must be somebody's business to do it; and we begin to hear of county road and of State road engineers. Certainly the existing method of letting ignorant men annually plow and shovel up the road washings from the gutters back into the middle of the road, and so on ad infinitum, while a fair way of producing mud and dust, and a lazy man's method of frittering away the public funds among a set of lazy men, who possibly have contributed some share of them; while an excellent method of how to accomplish no good, will never make roads fit to be called roads; and when pursued by each town at its own sweet will, becomes a system as barbarous and disgraceful as may well be conceived, following a study of how good roads are built and maintained throughout those countries that have them. It is an encouraging sign that the great States of New York, New Jersey and Pennsylvania, as well as others in the South and Southwest are simultaneously moving in the matter of better roads throughout

their respective territory—even though this agitation comes now, fully twenty years after our own commonwealth of Massachusetts made a move in the same direction. To have better roads must and will call for wiser road legislation; and with wiser road legislation will come a call for the civil engineer to build and maintain these better roads; to that extent will come some advancement of the profession of the civil engineer.

The tenacity with which anything approaching the office of a civil engineer, is in State governments, dubbed State engineer, and the way in which such men are instinctively made use of, for work which comes within the province of a State engineer, is an encouraging sign, looking to the advancement of the profession.

Thus, in Massachusetts, there were at one time a series of individuals, popularly called State engineers, although no such office existed. While they were in office they were naturally called upon to advise in various works in which the State had an interest; for, as may surprise many to hear, the State constantly has engineering work in hand; although political philosophers keep right on talking about the inadvisability of the State doing public work, about our form of government not being suited to the carrying on of public works, and the like platitudes derived from a study of the colonial period, or from that of the philosophies which are most followed in those countries which do *not* excel in their public works and are *not* followed in those countries that do.

The matter appears to be a very simple one; we want good roads; we want various other State engineering work done, such as systems of main drainage, the regulation and control, in some remote more perfect age, possibly, the operation of railroads; as far as Massachusetts is concerned, she wants and needs, a shorter, an ordinarily safe, and free waterway, from Massachusetts Bay to the Sound; and we want these things built in manner and form so as to have a dollar do its maximum of work while it is thus engaged, in shaping the State for the use and convenience of man.

To accomplish this, the forces of the State must be organized for these purposes; the State must not have its engineer corps disjointed; all engineers mere temporary makeshifts, hid away in the offices of a mess of hardly less temporary, or less disorganized, commissions, of greater or less tenure of life; rather let them see the light of day, and be seen of men. Let the State not be ashamed to have civil engineers in its employ. Let the State call upon *them*, to do its civil engineering work, and not have their knowledge and work come to it, filtered through, and may be distorted by, the untrained minds of an overslaughing mass of members of temporary commissions, or of still more temporary committees. The difference is one merely between a make-shift organization, made from time to time, to suit the needs of the hour; and a permanent organization made to meet the perpetual needs of the commonwealth. I have no fear but that with advancing time, will thus come a more and more permanent organization of the creative forces of the State, and with it, an advancement of the profession of the civil engineer, throughout the land.

I see signs of this, in the placing of civil engineers upon these various boards and commissions. Thus, in St. Louis, Mo., the Board of Public

Works is composed of the heads of the several city departments, such as water-works, sewerage, street-paving, etc., all civil engineers, and the President of the Board is himself a civil engineer. The President of the Kansas City Board of Public Works, is ex-officio the city engineer, and must be a civil engineer. One member of the Massachusett's State Board of R. R. Commissioners was by custom, for many years, a civil engineer; until for reasons which I do not care to characterize, but which cannot in the end prevail, the profession was deprived, and has until now remained deprived of the representation which is its due, on a Board largely doing the work of civil engineers, and supervising the railroads of the State, the very creations of the civil engineer.

For two other illustrations of the work of a State engineer being done in a hidden, furtive way, and as though the state were ashamed of it, when it might be that State's glory, I would point to the States of New York and New Jersey. By reason of its ownership of the Erie canal, the State of New York must have a corps of engineers to superintend the repairs of the canal, whose chief is termed the State Engineer, and who by reason of such appellation, is called upon to do various engineering work for the State. I will anticipate the arguments that will immediately be brought against public works of a State, drawn from the popular conception of waste on the Erie canal; not by a counter recitation of the benefits which this canal has conferred on the State and city of New York, but by the assertion that civil engineers are not put in position to make such waste impossible. If the works of the State were placed in charge of a permanent corps of engineers, such as we have seen, are employed in like cases on the continent of Europe, like results would follow from like situations. It is idle to talk of doing away with all public works; we always have had them, we have them now and always will have them. It is better to organize accordingly, and permanently; and in such organization the creator of these works, will surely, must surely, be given the charge of their proper maintenance and extension.

The other illustration which has occurred to me of State engineering having been done, in a thoroughly round-about way, and as though it were something to be hidden or apologized for, is illustrated by the beautiful topographical survey of the State of New Jersey. Here is an engineering work of the greatest practical value, done by the chance incident of an old time appropriation for a geological survey, continued and extended in its scope from year to year. New Jersey has taken the lead in thus picturing its territory, so as to show all the elements of a sculptured representation of that surface; a work of great and lasting use in any community; Massachusetts has lately done likewise, and other States will no doubt follow. Shall they wait for a fortuitous conjunction of favorable circumstances to get this work done in some round about, bungling manner; or shall an advancement of the profession of the civil engineer, to the point, that States have State engineers, render the accomplishment of this and other engineering works natural and in due course.

The inspection and control of railway traffic in Great Britain and her

colonies, and the improvement of rivers and harbors in the United States, are two parallel cases of an overslaughing of the civil engineer by the military engineer; in each case without good reason, and merely because the government has not been organized to do the work it has in hand, to the point of providing itself with a corps of civil engineers. Says a popular author in his "Departmental Ditties,"

> By the Laws of the Family Circle 'tis written in letters of brass,
> That only a Colonel from Chatham can manage the Railways of State.
> Because of the gold on his breeches, and the subjects wherein he must pass;
> Because in all matters that deal *not* with Railways, his knowledge is great.

To make the situation plain to American engineers, let us suppose all State R. R. Commissions abolished, and the Inter-state Commerce Commission doing their work on the railroads of the United States. This would be the equivalent of the British Board of Trade. Then let us suppose the Inter-state Commerce Commission calling upon army officers to do the work now done, either by engineer members of the State R. R. Commissions, or by the engineer employees of such commissions; and we should then have the situation which has been pictured in the Departmental Ditty above quoted, and which prevails throughout Great Britain and her colonies. Such use of army officers sounds ridiculous enough, but is perfectly paralleled by what we do in the improvement of the rivers and harbors of the United States. Here, if anywhere, is the work of a civil engineer; it is constantly with us; but instead of providing for its accomplishment, by a permanently organized corps of civil engineers, we detail officers of the United States' army temporarily for such work.

We first educate men by means of infantry, cavalry, and artillery drill, and by military studies to be soldiers, and then set them to doing something else; and to learn the art of the civil engineer, practically, on the work they are to do; all for the sake of deluding ourselves with the idea that the United States government does not need the services of a corps of civil engineers. Shameful, in the extreme, is the position in which this course places the large body of civil engineers who must of necessity be employed on these United States river and harbor works; and who constitute a pariah caste that can never rise above the rank of low-grade assistants to the privileged army detail for civil work. These works cannot be built without the aid of a very great number of civil engineers; and such are in the constant employ of the government, many times outnumbering their army masters; and in numerous cases, their superiors, in age, experience, or in knowledge; but they are not recognized by the government, and have positively no avenue of merited promotion. As a natural consequence the country is deprived of the services of its best men in this work; for no civil engineer will stay in such employment, that is not forced to do it, by stress of adverse circumstances. In the United States the profession can do nothing that will so much further its own advancement, as to educate the people and Congress to the great wrong that is being done it, by taking away from it work which is for the civil engineer to do; and by giving this work to army officers, temporarily

detailed for the purpose; to be done by them, and by the large body of their unrecognized civil assistants.

The appointment of the Inter-state Commerce Commission gave the President of the United States an opportunity to recognize the principle of appointing civil engineers to do the work of a civil engineer in a co-ordinate branch of the government. The commission is large enough—it is composed of five members—to have room upon it for men trained in the operation of railroads, civil engineers, and other experts, besides a due proportion of lawyers; but the president, himself a lawyer, appointed only lawyers.

Passing to the other extreme, there is no particular reason why railroad men and civil engineers would not have made a much more useful commission, one better fitted to control the railroads of this country for the use and convenience of man, than so many lawyers. Questions of law could have been left to the courts already provided, or the commission could have engaged counsel, as readily as another could engage the services of a civil engineer; and certain it is, that much work left undone, and for which the country is ready and anxious, would, in that event, long ago been, at least, begun. But in our day, the country is lawyer-mad, and it is no insignificant sign of the times to see a political party arising, which excludes lawyers from *all* participation in the government of the country.

Men will naturally undertake work for which they have been fitted by past training; which they have learned to like. In other of the world's work they as naturally remain passive. They do not see it waiting to be done; they do not hear the demands made that it be done. Thus it naturally came to pass that with a crying need for a regulation and for a unification of numerous railroad safety appliances, which none but a national organization could supply, the Inter-state Commerce Commission saw nothing of all this, and did nothing. Spurred to take up these subjects by conventions of the State Railroad Commissions, it nevertheless neglects them, and instead, spends the bulk of its time and energies in judicial work which is largely superfluous. Prominent men in railroad life, men who do not usually write for newspapers, have been spurred by the pity of the situation to write to the same effect. Many editorials have had this for their theme. I quote a few such utterances called during the past two years.

Mr. T. F. Oakes, President Northern Pacific Railway, said this:

"I think most railway managers are agreeably disappointed with the workings of the Interstate Commerce Law; that is to say, they find by experience that it does not injure their business as seriously as they anticipated, or cause them as much annoyance in the management of their affairs. This is due, without donbt, to the able and conservative character of the commission, which is composed of fair-minded men of judicial temperament and with no leaning toward demagogism. *The only criticism that can be made in relation to the commission from a railway point of view, is that its members are all lawyers.* It would be strengthened if one of its members, at least, were a practical railroad man.

"The railway transportation problem is a vast and complicated one. It touches all interests, industries, and classes, and is closely interwoven with the whole fabric of our modern civilization. The longer a man is engaged in the active business of railway management, the more he finds that he has to learn. A body composed exclusively of lawyers, however able and patriotic, can hardly be said to be equipped with that special knowledge which is often an essential thing in the right decision of questions arising before the commission. It is hoped that when the next vacancy in the commission is to be filled, the new member will be a man who has had large experience in practical railway affairs.—*Frank Leslie*, May 25, 1889.

From the *Railway Review*, Sept. 7, 1889, I take this:

"The appointment of Judge Veazey, of Vermont, as a member of the Interstate Railway Commission, to fill the vacancy occasioned by the resignation of Mr. Walker, may be above criticism as far as the judge's personal worth is concerned; but it surely is an error to place another lawyer upon the commission. Mr. Walker's retirement gave an opportunity which should have been improved, to place a practical railroad man upon the commission. It has been fully realized that such a man could prove of the greatest aid in increasing the efficiency of the commission's discharge of the duties assigned to it by congress. The legal members are useful in interpreting the law; their peculiar talents are indispensable: but in the application of the law, as construed by the legal members, the services of a man thoroughly familiar with the intricacies of railway operation and management are sadly needed. This fact is so well understood by the general public, as well as those who have given especial study to the matter, that it is strange that the president should have ignored it.

Bradstreet's, Sept. 20, 1890, had this:

"The Interstate Commerce Commission has passed judgments by the score, but the courts, and they alone have authority to determine what may be and what may not be done under the statute.

There has been heretofore among railroad managers on the one hand too great subserviency to the opinions of the commission, and on the other hand too great disregard of them. Lately, however, in connection with the judicial decision that party rates are lawful, a decision which the railroads have promptly taken advantage of, to the benefit of both themselves and the public, as well as in connection with sundry prosecutions for violations of the law, the function of the courts under the act seems to be receiving more attention than formerly. At the same time the proper place of the commission is gradually gaining better recognition. It is a body whose opinion and advice in regard to many matters of traffic, though valuable and worthy of consideration, and perhaps in most cases sound, are not necessarily conclusive."

It must be remembered, that there are 40 odd United States' judges scattered about the United States, any one of whom, by a turn of the hand, can upset the penibly arrived at law conclusions of the commission. They have done it time and again, and will continue to do it. Under all the

circumstances, one would say, that the commission had better stop holding so much court, and do work more essentially railroad work, and needful to be done for the use and convenience of man; also be constituted with that object in view. Such commissions are composed, in other countries, entirely of experts, with the possible addition, or having for its advisor, on legal matters, one member of the bar. I believe the United States would profit by a change made in this direction; and that such a change must come, that it is, indeed, now in process of being effected. It must come, if for no other reason because it is part of the advancement of the profession of the civil engineer in these United States.

In common with the other professions, the civil engineer is called on to aid the machinery of justice in turning out as near an approach to perfect justice, as weak, limited humanity, may be capable of effecting. But his is the questionable distinction, of having helped to deflect the whole course of the development of the law in this particular branch of expert services, in English speaking countries; and of having, in this manner, produced the opinion or expert witness; that is, a witness called in court to give opinions, and to be cross-examined upon these. A very anomaly, upon the last analysis; for however useful cross-examination may be to strip facts of embellishments, or to expose mendacity, its application to an opinion, and endeavoring to twist the laws of testimony, in general, to apply to opinions, is sure to lead to disappointment and to failure. We find, indeed, that lawyers and legal authorities are agreed on the worthlessness of expert testimony as now constituted, in aiding courts of justice; and study will show that it can be of value, only, under the particular circumstances under which it arose.

The leading case (as it is called by lawyers) is Folkes versus Chadd, tried in 1782; during the course of which, it was proposed to call John Smeaton, Civil Engineer, to give his opinion from the witness stand; a thing then and there permitted (for the first time, in English legal history, be it noted) by the presiding Justice, but under these circumstances. John Smeaton was the first man, in English speaking countries, who called himself, a civil engineer. He was held in high esteem by his contemporaries, had been the builder of the Eddystone Light, the first of modern lighthouses, considered then one of the marvels of human handiwork; and was, practically, the only civil engineer in England. Both sides, and the presiding Justice, as may be gleaned from the records of the case, held him in high respect; both as to his knowledge, and as to his judicial temperament; and were practically ready to let him, with his superior knowledge of the facts, and of their bearing and meaning, fairly decide the technical part of the case in hand. It was one relating to questions of tide water marsh drainage. Under such circumstances, it is easy to see how such an expert witness could aid in the administration of justice; but it would be more proper to have called him what he was, and what the law or codes of the continental countries would have then called, and would still call him; namely, an expert, summoned, actually or constructively, by both parties, or by the court, to get at all the technical facts; whether by hearing all the testimony, or by research made upon his own initiative; and then to

report his opinion, and conclusions upon these to the court, so as to aid it in arriving at a judgment upon the whole case. This whole subject is fully discussed in a paper printed in 1888, by the Bar Association of the City of Boston,through the Committee on the Amendment of the Law; to which I will refer those who would read further upon it.

It would contribute to the advancement of the profession of the civil engineer to have a reform brought about in this matter of a better use being made of expert services in the conduct of judicial enquiries; and we may count, in such endeavor, upon the aid and sympathy of all the other professions, of the legal profession amongst others. In-as-much as civil engineers foisted the conception of an expert, or of an opinion witness, upon the body of the law, it would be no more than proper, if their labors should tend, largely, to restore the pure stream of justice, as it deals with this and cognate subjects.

What can engineers do to promote the advancement of the profession? We have seen that in order to be a profession, they must, then, first of all, have given them the confidence of the public. They must make themselves worthy of that confidence. Their lot must be not only study, and learning, but practical application as well. Not the amusement, mainly, of pursuing science for science's sake, but the art of directing the great sources of power in Nature, for a purpose; namely, for the use and convenience of man. The engineer must know how to direct and how to wield natural resources; his business is such direction, and application; whence it follows, that in him the hand and the executive abilities, need a training quite as much as the intellect. Lacking these, he speedily changes and becomes the craftsman surveyor, the measurer of quantities, or the philosopher, or savant. On the other hand, without such opportunities for the exercise of the talent the profession can hardly be said to exist. Even now the Railroads of the United States are currently distinguished as those operated by civil engineers; and those, where the old time custom, of putting men in charge, more or less lacking in the proper qualifications for their work, still prevails. Inasmuch as the model railroads of the country belong, and have long belonged, to the former class, railroads would seem to have profited by this form of advancement of the profession of the civil engineer.

For some occult reasons, some railroads, especially in the N. E. States, still hold to the idea, that to have been the driver, or even only the baggage master, of a four horse stage-coach, on that route, and before the railroad was built, conferred superior qualifications, to operate a modern railroad upon the individual in question. Some of our principal railroads have not yet discovered that it is the business of a civil engineer to design bridges; and fritter away opportunities and money, by letting some boy in an architect's office or the road carpenter, try his prentice hand on such bridge as they may have occasion to build or to renew. The advancement of the profession of the civil engineer, a mere recognition of the profession, should make such mistaken action impossible.

Another illustration of the profit that comes to corporations operating works of engineering, from placing engineers in charge of them, might be

drawn from the experience of some of our large N. E. water power companies.

Surely those of them who have placed their engineers in responsible positions are acknowledgly better, more profitably, conducted, than those who flounder along under inexpert guidance. The advancement of the profession of the civil engineer will make the resident executive conduct of a water power company, by any one not a skillful hydraulic engineer the memory of a bye-gone age and an absurdity.

Besides being fitted for it, engineers must themselves strive for the advancement of their profession. They cannot aim at money-making first; to do so would be to sink the profession. It is even now threatened with dissolution into a group of contractors for various engineering works. A man should at the outset clearly make up his mind whether he will join one such group or be a civil engineer. It is but seldom that the change can be made in after life from one occupation to the other. The civil engineer, must, in common with other professional men, be prepared to suffer in the upholding of his profession. It is only by such suffering, that unselfish work can be accomplished in this world.

One of the profession has well illustrated this. Says he:

"The engineer is the van-guard of civilization, whether it be in the form of a prospector for the material resources of the earth or in the domain of mind. He must be in advance of, or at least abreast with, the times, never in the rear, if he would not lose his rank. He must either have invented the new systems which have done so much to elevate humanity and cheapen products, or have been able to execute such projects when conceived by others, though in so doing he may have, and often has, stood in peril of his life. History is replete with instances of tumult, arson and murder because of the attempt made at various time to introduce labor-saving machinery, or to construct a new and more speedy line of communication to supply a community with better light, more water, better power, etc. Every one of our readers will recall numerous cases of opposition to every proposed change in means of transportation from the pack-saddle through a wilderness, to turnpikes, plank roads, tramways, canals and railroads; and in the rolling-stock, from the burro to the locomotive, or from the Conestoga to the palace sleeper.

But what has all this cost? As a tribute to the perseverence and energy of the early engineers, whose memories are still cherished and whose works are their mile stones, and as a finger post for future travelers along the highway of engineering we beg leave to say that there is an experience so invariable as to be enunciated as

A Law of Development.

The successive stages of which are marked by

PREPARTORY.

1. *Ignorance* on the part of the public to the project.
2. *Indifference* to the proposed benefits after they have been stated.

3. *Incredulity* by those who, knowing nothing of the resources of science, deem the scheme impracticable, or physically impossible.

INTERMEDIATE OR PROGRESSIVE.

4. *Argument*, which follows from the above, and other conditions.

5. *Denunciation*, after the projectors of the works have established their points.

6. *Ridicule*, when argument and denunciation fail.

FINAL.

7. *Violence*, the successor of 4, 5 and 6, and result of persistence in efforts to construct the work.

8. *Persecution*, sometimes even to death, from continued perseverance in the improvement.

9. *Success*, if all the above are outlived. *Haupt*.

Engineers have then no easy berth in this world or country of ours. They are barely recognized as a profession; it is with difficulty that they can ever be fully fitted to meet the requirements of the position they should occupy. But there lies clearly before the profession a most glorious future. With advancing knowledge, with a growing complexity of the requirements of modern life the work of the engineer is necessarily increasing. He has but to be true to the profession to make clearer and more appreciated its standing; until that time when it will no longer be necessary, as it now is not necessary with regard to most of the other professions to so much as speak of the advancement of the profession of the civil engineer.

THE INJURIOUS EFFECTS OF CEMENT ON LIME MORTAR.

A Discussion Before the Civil Engineers' Club of Cleveland.

[December 9, 1890.]

Mr. Clarence O. Arey read from a technical journal an article entitled, "The Injurious Effects of Cement on Lime Mortar."

As prefatory to the reading Mr. Arey mentioned that the announcement in regard to his reading a personally prepared paper was rather misleading; that it was simply his intention to read an article on the subject above mentioned which he considered quite pertinent and interesting.

The reading of the article was followed by an informal discussion on the points brought up, of which the appended is the purport, in substance:

* * * * * *

Mr. Richardson:—A good many claim that the mixture would not do—would not work satisfactorily. I have had masons state to me that the combination of first-class lime mortar and cement was the best.

Mr. Eisenmann:—My experience is somewhat similar to Mr. Richardson's. There was a time when I favored it, being under the impression that its "staying qualities" were better—that is, that it was more lasting, and would wear better with the addition of lime than without it.

As a consequence of the fall of the temperature of the atmosphere the temperature of the lime becomes greater.

The practical effects obtained from the use of Louisville and cements of that class, would probably be very interesting.

I have not seen in any notice written by any authority an account of the methods accepted by the local builders who make good walls and use it successfully. (Mr. Eisenmann, at this juncture, illustrated his remarks by a sketch.)

In regard to the Arcade, of Cleveland, with the building of which Mr. Eisenmann was connected, Mr. Thompson said:

Did you use any lime mortar?

Mr. Eisenmann:—There was no lime-mortar used in the construction of the Arcade below the sixth story; then we began to use a small proportion, and as the weather grew colder we used as high a proportion as from one to two. We tried it with a knife and found it a little softer than that below. It did not have the weight on it the lower portion had. The settlement due to the weight of the walls is reduced to a minimum.

Mr. Thompson:—I have not had much experience with lime mortars. It would seem to me that lime mortar would have something of the same properties limestone has, and I have knowledge of an instance where cement failed to bond with limestone; but using the same cement with sandstone a perfect bond was secured. We will get a much better bond where there is pressure. Many builders lose sight of the fact that the cement mortar in settling gives out water.

I have tried experiments with the different cements where the mixture of mortar was so dry that it crumbled, and when I came to press it into the walls it was so wet the briquettes were almost useless—I could not get anything out of them.

Mr. Eisenmann:—It depends entirely upon the material you are building with. In the ordinary class of building, where common brick is used, the absorption of the material is the principal thing we have to contend with.

Mr. Thompson:—I think it necessary that the material you are building with should have absorbent properties in order that your mortar may make the proper bond. If the mortar you are building with makes a mass equally strong with the material, the material will break first. The ordinary wall laid up with common limes settles very much indeed. This is due to slowness in the absorption of the carbonic acid.

We find that up to ten or fifteen years ago the Germans never attempted to build in freezing weather, supposing that it had the effect of deteriorating the mortar; but it seems that if the mortar is once in position and kept frozen, there will be no damage done.

MR. HERMANN:—Some masons use salt in their mortar in freezing weather—that the salt is mixed in to keep the mortar moist.

MR. EISENMANN:—The reason salt is put in is to reduce the freezing point.

On the seashore we do not like to use sea washed sand.

MR. HERMANN:—I have a piece of brick work in my house that was laid up with salt. I have not noticed any difference between it and another style.

MR. EISENMANN:—In ordinary brick work, in the course of time, this will wear out.

MR. HERMANN:—About a year ago there was a great deal written in the papers about using sugar in mortars; and I have tried experiments with it.

MR. AREY:—In the winter of 1885-6, I put up two buildings. In one I used Louisville cement—three to one, with sand; and in the other I used lime-mortar and cement mixed. The one laid entirely with cement was finished before October; the other one was finished about this time of the year. In the one in which all cement was used I tried it next year and it did not strike me as being extra strong. In the case of the other one I examined it carefully and found the mortar rather soft; towards the end of the summer it became very hard, much harder than the first-mentioned mixture.

MR. MORDECAI:—To get the best results there ought to be used one part of lime to six parts of cement.

MR. MORSE:—In laying cement, in either brick or stone work, during cold weather, and it continues freezing right along, do you think we would get good work?

MR. EISENMANN:—Yes, sir.

MR. MORSE:—I do not think it is good policy to use common white lime with cement.

MR. EISENMANN:—In this vicinity it is cheaper to use a mixture of cement and sand.

MR. AREY:—I noticed in a paper that the addition of sugar to lime mortar would give as good results as cement.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

WESTERN SOCIETY OF ENGINEERS.

278TH MEETING, FEBRUARY 4TH, 1891:—The 278th meeting of the Society was held at its rooms, Wednesday evening, February 4th, at 8 P. M., President L. E. Cooley in the chair and over forty members and visitors present.

The reading of the minutes of the last (annual) meeting was dispensed with, with the exception that Mr. Richard P. Morgan said: At the Annual Meeting I gave notice to the Society that at the next regular meeting I would present for its consideration a change of its name to that of the Chicago Society of Civil Engineers. I notice that was omitted from the minutes, and I would like to have that notice inserted in them.

The subject seemed to me to be one of importance, and, of course, to give notice of that kind in parliamentary usage is always in order, and therefore I gave that notice, and rather than detain the meeting to-night, I will give notice again to-night that at the next regular meeting I will present for the consideration of the Society the changing of its name to the "Chicago Society of Civil Engineers."

The Secretary explained that the omission was an oversight, due to the telegram having been lost sight of in the accumulation of letters and papers at Annual Meeting. It was, however, presented at Annual Meeting.

The President suggested that Mr. Morgan present the matter in the course of the evening, in which Mr. Morgan acquiesced.

The Secretary then presented the following names elected by Board of Directors: Messrs. Frank W Barker, St. John V. Day, D. C. Jackson. Wm. G. Potter, E. R. Schnable, omitted from January 7th proceedings. Mr. Willard A. Smith, *Railway Review*, resumed membership.

The following were presented as candidates for membership: Messrs. John Fraser, Geo. W. Sturtevant Jr., Alfred C. Schrader, Elam Gray, Frank H. Cooley, Oliver W. Child, Geo. M. Huss, Archibald R. Eldridge, James P. Mallette, Erik T. Eriksen.

The Secretary read a letter from Mr. W. F. Goodhue relative to improvements in diploma, etc. Referred to Committee.

The Secretary for Committee on International Engineering Congress and Joint Headquarters reported most satisfactory progress.

The President in calling for reports of Standing and Special Committees said: We have several committees which have been appointed during the past year, and perhaps there are some new ones which it is desirable to appoint, and I therefore think it would be worth while to call them all up in succession this evening to learn what state of progress their work is in, with a view to seeing whether it is desirable to take any further action in the matter, perhaps not at this time, but at some meeting of the Society, possibly the next meeting, to bring them before the Society. The first one I have on my list is in regard to National Public Works, of which I am Chairman.

I have to say in regard to that Committee that it is in the nature of a standing committee, constituted for the purpose of keeping track of that question and reporting at any time to this Society. Nothing has occurred thus far to call for any action on the part of that Committee, but I may say that a report will be made in the course of the next two or three months, bringing the matter down to date, for the information of the Society.

We would like to hear from the Committee on Bridge Legislation, Mr. Chanute, Chairman.

Mr. Chanute:—The Committee on Bridge Legislation has gathered nearly all the information which it needs. It has obtained the practice in foreign countries as well as in this; it has obtained some of the laws which have been proposed for the regulation of bridges; it has yet to adjust the material obtained, and to write the report. This cannot take very long, and we hope within a month to present a full report to the Society.

President Cooley:—The Committee on the Railroad Problem of Chicago, etc., Mr. Morgan, Chairman.

Mr. Morgan:—As chairman of that Committee I have to state that the committee has made very satisfactory progress in collecting information from all parts of the world, especially as to terminal facilities of the different railway systems in this country and in Europe. They have had meetings as frequently as the presence in the city of the members of the committee would enable them to do; the work is in a fair state of progress.

President Cooley:—Committee on Affiliation of Societies. I believe such a committee was constituted last June; they made a report and I think it was continued. Is any member of that committee present? Mr. Chanute do you know what has been done?

Mr. Chanute:—That committee made a report to the Society, which was forwarded to the American Society of Civil Engineers, and that has been taken in due consideration. It is understood that a new charter is now pending before the American Society of Engineers; until action can be taken on it there is nothing for this committee to do; it may be continued or it may be discharged, as this Society sees fit.

President Cooley:—A committee was appointed on Sanitary Engineering among the standing committees of last year; are any of those present to report? Has any progress been made? I think there are no members present, and I have not learned of any activity on the part of that committee, and the President will direct the Secretary to ascertain whether it is alive, with a view to some action in the premises at the next meeting, should it be expedient.

Committee on Municipal Public Works. Is any member of that committee present? I will say for the chairman of the committee, who is out of town, that he contemplates getting it into active working shape as soon as he returns, in the course of two or three weeks.

Committee on Topographical Survey, etc. Any member of that committee present?

Secretary:—I have the resignation of Mr. L. L. Wheeler, the chairman. All I know is that Mr. Wheeler found it impossible to get that committee together for some reason or other, and gave it up.

President:—I will make the same direction in regard to this committee as for that on Municipal Public Works, that the Secretary will ascertain what he can in regard to it.

For Committee on Badge, etc., authorized at annual meeting, I would name Mr. Wm. G. Karner, chairman, Mr. Liljencrantz, and Mr. McKee.

The Society having reached a membership of over 350 members we are entitled to another representation on the Board of Managers of the Journal of the Association of Engineering Societies. Nominations by the Society are now in order.

Mr. John F. Wallace nominated Mr. John Nichol, and there being no other nominations, it was put to vote and carried.

The President then called upon Mr. Richard P. Morgan to present his matter in relation to change of name of Society.

Mr. Morgan.—Mr. President, in presenting this subject, inasmuch as a notice was not given out formally, I do not desire to withdraw the second notice which I gave this evening, and would like to have that form part of the record, as I shall not make any final motion to-night. I will just bring it before the Society, and then at the next regular meeting probably make the formal motion. I am not unaware of the importance of this subject; I feel that it is very important and perhaps imprudent for me to bring it forward.

My object in having the notice is,—it is an important subject I think, and of

course every member of the Society ought to have an opportunity to know about it, and to know so that he may take such action as he thinks best.

Mr. President and Gentlemen:

At the annual meeting on the 7th ultimo, I gave notice that I should at the next regular meeting, present for the consideration of the Society, the question of changing its name to "The Chicago Society of Civil Engineers." The article proposed to be amended is Section 1 of Article 1, which is in these words:

Sec. 1. The name of this association shall be "The Western Society of Engineers."

A question so important should not be raised without at least careful consideration on the part of the mover, I have, therefore, deliberated for several months before taking action, and trust you are assured that what I do springs from a hearty desire to promote the best welfare of the Society.

In our personal affairs it is a good rule of action to endeavor to attend first to the essential things of life: the most essential first and so continuously. The non-essentials will even then clog our way to success.

This rule doubtless applies with equal force to our Society, and it is for that reason I desire to urge upon the attention of its members the importance of establishing for it in perpetuity, a name that shall be accurate, appropriate and distinctive.

A few of the reasons which most commend the change suggested, or some change, are found in the vague and complicated character of the present title of the Society.

The name by which it is now known, has in itself neither habitation nor its proper distinction. The term Western Society, conveys, especially to cosmopolitan minds or societies with whom we should hope to associate, an indistinct idea of locality, anywhere west of Greenwich or Washington to any meridian of longitude. Eliminate Chicago from our letter heads and the Society would become one of the lost tribes.

Five of the eight societies in our association are located west of Chicago, and only two, those of Boston and Cleveland east of that city.

This illustrates briefly what has been said in respect to the vagueness of the present name of the Society. I can see no good reason why we should not adopt the distinctive word, Chicago, in the same manner as all the other associate Societies, except that of Montana, have localized themselves by their names.

The prominence of the city of Chicago, it being now the second, and probably ere long, to be the first city in America in population, and now the greatest railroad center in the world, seems to furnish a paramount reason for the use of its name in the title of our Society.

Besides this, Chicago is no longer justly called a western city, that appellation was appropriate a few years ago when it came into use, but the extraordinary developments in recent years of the trans-Mississippi territory of the United States, has made Chicago a central rather than a western city, and it will always remain so.

Civil Engineers find their employment along lines of commerce, aud the focal point to which lines of transportation and commerce converge would seem to be the point whose name should distinguish the society which meets there.

In respect to equality of advantage, would not the benefits which any member would receive from his connection with the society, however remote his residence, be increased rather than diminished by the proposed change of name? It is already known that this Society has arranged for a congress of the engineers of all nations, to be held at Chicago during the Columbian Exposition.

This is another reason why the name of the Society should indicate its location and not leave that to be inferred, because the foreign guests of the Society should receive, carry away with them, and communicate the most distinct impressions possible.

In the concluding words, "society of engineers," is a complication which, as it is beyond control, should be avoided, even if the expression is strictly accurate.

The word engineer in common parlance is inaccurately used to include every man who operates locomotives, stationary engines, and engines of steam ships, tugs, steam thrashing machines and the like; but in fact engineers are only of two kinds, military and civil. Our Society is of the latter class, which is again subdivided into mechanical, mining, electrical, hydraulic and many others, according to the subject to which civil engineers devote themselves. Accurately speaking, all engineers are civil that are not military, but to avoid the confusion arising from the improper popular use of the word engineer, which in this country is irrevocably established, it is proposed to call the Society one of Civil Engineers; this avoids the involvement perhaps as much as possible and includes all sub-divisions of the profession, to whichever special department any member may devote his attention, and leaves out all classes of engine drivers.

Fortunately located, in the most promising city in the world, under a distinctive and appropriate name, actuated by the true spirit of scientific progress, may we not rightly hope to conduct our Society to an eminence equal to that attained by any other.

Mr. Philbrick moved that the remarks and notice of Mr. Morgan be incorporated in the proceedings to be issued in due course.

The President then called upon Mr. O. Chanute for his promised remarks on the Paris Exposition of 1889:

MR. CHANUTE:—Mr. President and Gentlemen: What I have to say this evening is chiefly in the way of rectification. I had the pleasure, almost exactly a year ago of giving you an account of what the Paris Exposition was like; it was the 5th of February, one day of being a year from this time; the remarks that I then made were published in the July transactions, and I sent some copies to Paris to some of my friends. I received letters from some of them expressing the opinion that I had given an inadequate impression of the part played by the civil engineers in designing and building and managing the French Exposition, and finding that I have unintentionally, through want of more accurate and full information on my part done them an injustice, I desire to rectify it. At this time I received letters from Mr. Contamin, who is not only the President of the French Society of Engineers, but he was also the chief engineer of the exposition.

Mr. Chanute continued from written remarks to explain the policy adopted in the management and carrying out of the great undertaking, strongly contrasting the same with what appears to be the system prevailing in our own Columbian Exposition programme.

It was expected that considerable discussion would ensue, but the condition of the question in Chicago seemed to be a puzzling one to the members of the Society.

Mr. Geo. S. Morison upon being called upon said:

The subject is one which I have not given much attention to. I visited the Paris Exposition of 1878, and I really think there was room for a great deal of improvement there in the construction of buildings. Parts of the buildings were very fine and very well arranged, but a great deal of space there was at a very low elevation, which of course would account for the much greater price per cubic foot; still that is a detail which cannot be discussed; it is only a matter of examination of plans. The subject of the Columbian Exposition is one I am rather ashamed to say I have given practically no attention to whatever. I hope to see it a success; that is about as far as I have gone in being active myself; I believe it will be a success. I think one thing must be remembered, however. The Exposition of 1876 certainly was a great success, and the various delays and hindrances which are now being complained of in Chicago, as far as I can remember, existed in even a greater degree in Philadelphia in 1874. There was a period in 1874 when the general impression was that the whole Exposition would prove a failure. I remember one Philadelphia man saying that if they wanted to make it a success they had better put it in the hands of Barnum.

PRESIDENT COOLEY:—I would like to know if anybody here present can give us an outline of what the organization is upon which the World's Fair Directory is doing business; how the business is managed, as a matter of information. I confess that I have very little knowledge of the subject and would like to know how the

business is done there. How they get at things. I hear about committees on transportation and committees on site and committees on buildings and committees on this and committees on that.

Mr. Schmidt:—I think the two main committees are, the committee on buildings and the committee on ways and means. If you have got any project you must go before the committee on grounds and buildings, and then it goes to the committee on ways and means and the financial question is settled there.

President Cooley:—Is there a general executive committee anywhere that determines and directs what shall be done, that acts as motive force to these various committees, a centralizing agency of any kind whatever?

Mr. Schmidt:—I think that is one point that is not in existence.

Mr. Morgan:—Is there not a Director-General?

President Cooley:—That is what I am trying to get at,—what the functions of the Director-General are, and what their relations are. I understand that the Director-General has the power of appointing heads of bureau and things of that sort, to represent the various exhibits, with the view of having these exhibits gathered here, and with the view of having an exhibit prepared; but that he has anything to do specially with the question of transportation, buildings, grounds, or organization, I am not informed. That he was rather an agent of the national body, than having anything to do with the buildings and grounds and plans. I do not know whether I am correct or not in regard to that.

The discussion was continued by Messrs. Max. E. Schmidt, O. Chanute, Richard P. Morgan and the President, chiefly on the organization of the Columbian Exposition, but little information was obtained, and in reply to a question by Mr. Cooley:

Mr. Chanute said: The one point I want to emphasize is, that the work was chiefly done in Paris by the use of one man power; that there were no committees, and that no intermeddling was permitted; that the men, after they were selected, were clothed with full power and authority, and held responsible for the results; that the effort was to simplify and unify as much as possible, instead of doing the work through committees, which are. as we know, always hard to get together, and from which it is always difficult to get reports, as the President of this Society knows, and who are generally inefficient.

Adjourned. John W. Weston, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

Fourth Annual Meeting, January 17th, 1891:—The following members assembled at 8:00 A. M. on board a special car attached to the Northern Pacific Railroad train for Marysville, viz., E. H. Wilson, A. B. Knight, H. B. Davis, Charles Tappan, Sigmund Deutsch, A. S. Hovey, Finlay McRae, G. O. Foss, F. J. Smith, H. V. Wheeler, F. L. Sizer, E. H. McHenry, John Herron, C. S. Haire, L. R. Lothrop, H. J. Horn Jr., E. H. Ellison, C. F. Pearis, B. H. Tatem, and J. S. Keerl. The following invited guests were in attendance: Hon. H. N. Blake, Hon. W. H. DeWitt, Hon. E. N. Harwood, Justices of the Supreme Court, Montana; A. D. Edgar, General Agent N. P. R. R. Co.; Prof. A. M Ryan, Professor in the School of Mines, College of Montana; J. M. McKnight, Editor Helena *Journal*; Messrs. Samuel Bundock, W. L. Darling, and J. B. Tompkins. Civil Engineers; F. E. Worcester, Mechanical Engineer, and A. R. Beary, Society's Stenographer.

Arriving at Marysville the party was met by Manager R. T. Bayliss and Assistant Manager Geo. H. Robinson of the Montana Company—members of the Society—who escorted the party to the General Offices of the Company. After partaking of light refreshments an inspection was made of the mills and other surface works; Messrs. Bayliss and Robinson and their assistants taking great interest in explaining everything. At noon the party was entertained at a magnificent lunch, prepared by Mrs. Bayliss and Mrs. Robinson at the General Offices of the Company.

Soon after lunch the party started upon an inspection of the mines, and spent about four hours underground. Much interest was shown in the workings, which evidenced a thorough and intelligent direction. A spiral registry—an invention of an employe of the Company—attracted particular attention. It is worked by electricity and keeps before the man who works the cage the position of the chairs at the different levels, making it impossible for an accident to occur to the cage while descending, through collision with any of the chairs, if the man working the cage is attending to his business. The party left the mines fully impressed with the conclusion that the plant of the Montana Company is one of the best in the country.

Returning to the general offices, Assistant Manager Robinson deeply interested the engineers of the party by exhibiting a new and elaborate mining transit, constructed by Messrs. Buff and Berger, from designs furnished by him, and intended, especially, to secure that refinement of work required in deep shaft alignment. He also kindly showed his other mining instruments, of which he has an outfit so complete, as to be the envy of all who saw them.

On leaving, Mr. Elliott H. Wilson, of Butte, thanked Messrs. Bayliss and Robinson and their wives for the kindness shown the party, a sentiment received with cheers.

Manager Bayliss responded as follows: "I thank you, gentlemen, in the name of the Montana Company, for your presence and for the cheers you have so heartily given. I feel it a duty and a pleasure, which a company like the Montana owes to your profession, to entertain such worthy members. Were it not for the profession, such mines as the Drum Lummon and other great ones would not now be in existence. We are pleased that you have all enjoyed yourselves, and if you find no other place to spend your next day of meeting, we extend a hearty invitation."

Returning to Helena, the Society held a business meeting at 8:30 P. M., in the office of Mr. L. E. Johnson, Superintendent of the Montana Central Railway, Mr. John Herron, 2nd Vice-President, in the chair. There were present twenty-one members and four visitors.

Minutes of previous meeting were read and approved.

The application of Mr. Franklin E. Worcester for membership was read and ordered filed.

The following names were proposed for membership without written applications, viz :—Prof. A. M. Ryan, W. L. Darling and Samuel Bundock. Moved and carried that the rules be suspended and that these gentlemen be included in the usual letter ballot, upon their filing with the Secretary their written applications.

A letter from Mr. John W. Weston, Secretary, was read, relative to the proposed Engineering Headquarters and International Engineering Congress, to be held during the World's Exposition, 1893. The question of making an assessment in support of this movement was discussed, and the prevailing sentiment was to meet the matter in a liberal spirit. No decisive action was taken and the question was laid on the table to await further advice from Mr. Elliott H. Wilson, the Society's representative on the permanent committee.

The Secretary's report was submitted and read as follows:—

ANNUAL REPORT OF THE SECRETARY AND LIBRARIAN.

HELENA, Mont., January 17, 1891.

To the President and Members of the Montana Society of Civil Engineers:

GENTLEMEN:—I have the honor to submit my report as Secretary and Librarian of your Society, covering the period since my appointment as Acting Secretary on May 31, 1890, to this 17th day of January, 1891.

RECEIPTS.

During this period the amounts paid to me as Secretary, have been as follows:—

Received on account of Initiation Fees	$ 15 00
Received on account dues for 2nd one-half of 1889	15 00
Received on account dues for 1890	304 50
Total receipts	$334 50

This amount has been paid to your Treasurer, A. S. Hovey, Esq., as per vouchers attached. Orders have been drawn on the Treasurer, covering the following distribution:—

For amount placed to credit of Treasurer as overdrawn	$ 25 07
For assessments account Association of Engineering Societies	97 00
For printing and stationery	55 90
For clerical services rendered Committees and Secretary	56 50
For incidental expense account of Secretary	37 50
Total expenditures	$271 97

Leaving a balance in the Treasury of $62.53.

DUES AND FEES UNCOLLECTED.

Initiation Fees	$ 15 00
Dues for 1890	184 00
Total	$199 00
Balance in Treasury	62 53
Assets	$261 53

LIABILITIES.

Bills oustanding or contracted, about	$120 00
Expenditures authorized as follows:	
Transactions of Am. Inst. of Mining Engrs., about	90 00
Desk for Secretary	50 00
	$260 00
Net assets,	$1 53

There are now upon the Roll of Membership fifty-seven active and three associate members; six members have been added to the roll and two active members made associate during the past year.

During the year we have been called upon to mourn our second loss by death, G. A. Kellogg, of Philipsburg, Montana.

Three members have been dropped from the Roll for non-payment of dues, as directed by the meetings of October 18th and November 15, 1890, and one resignation is of record.

During the year ten regular, one special and one adjourned meetings have been held.

For a statement of the Transactions of your Society, I would respectfully refer to the minutes I have of record.

My books of accounts are herewith presented for examination and auditing by the Board of Trustees as provided by the By-Laws. I have the honor to be,

Your obedient servant,

J. S. KEERL, Secy. and Librarian.

Mr. Albert S. Hovey, Treasurer, submitted and read his report covering the past year. These reports, together with account books of the Secretary, were referred to the Board of Trustees, as provided by the By-Laws.

The Secretary was requested to supplement his report by a statement covering the period from January 18, 1890, to his appointment as Acting Secretary on May 31, 1890, that the total business of the past year might be shown.

Messrs. F. L. Sizer and Finlay McRae were appointed Tellers to count the ballots received for officers for the ensuing year, and reported the following as elected:

President, Elliott H. Wilson; First Vice-President, John Herron; Second Vice-President, George H. Robinson; Secretary and Librarian, James S. Keerl; Treasurer, Albert S. Hovey; Trustee for three years, W. W. DeLacey.

Installation of officers being in order, upon motion, Col. DeLacy escorted Pres. Wilson to the chair. The President elect thanked the Society for the honor they

had conferred upon him and promised his best efforts in advancing its interests and influence.

A vote of thanks was tendered Messrs. Bayliss and Robinson of the Montana Company for the entertaining and instructive day passed, through their courtesy, at Marysville; also to the officials of the Northern Pacific Railroad Company, and the Montana Central Railway Company for the highly appreciated favors shown the Society upon this Fourth Annual Meeting.

The meeting adjourned to the Hotel Helena, where being joined by invited guests, the Annual Banquet was enjoyed. Twenty-four members were in attendance and seventeen guests.

President Elliott H. Wilson was Toastmaster. Toasts were proposed and responded to as follows: Old Times in the Northwest, Col. W. W. deLacy; Future of Engineering, John Herron; Matrimony and Its Relations to Engineering, A. S. Hovey; The Railroad Engineer, H. J. Horn, Jr.; Mining Engineering, A B. Knight and C. W. Goodale; The Law, Judge Hiram Knowles; Engineering Societies, J. S. Keerl; The Ladies, E. H. McHenry; Surveying in 1730, Judge H. N. Blake.

The banquet table was decorated with artistic pieces, emblematic of the profession engaged in by those who were seated there, various engineering instruments being worked in sugar and ices.

J. S. KEERL, Secretary.

FEBRUARY 14th, 1891.—A special meeting was held at 8:30 P. M. at the office of Messrs. Sizer & Keerl, Helena, to discuss the question of memorializing the Legislature of Montana, looking to creating the office of State Engineer.

In the absence of presiding officers, Mr. W. A. Haven was elected Chairman.

There were present Messrs. Tatem, Sizer, Foss, Jones and Keerl.

A letter was read from President Wilson, stating that in view of the large amount of business now before the Legislature, and considering the short time that would elapse before adjournment, it might not appear advisable to memorialize the Legislature at this session, unless sufficient individual effort had already been made by the Society's members with the individual members of the Senate and House.

Following a discussion of the question, on motion, carried, Mr. W. A. Haven, was appointed to report to the next meeting, the proper action to be taken by the Society relative to the creation of the office of State Engineer.

After some further general discussion upon the question of whether it was better to have the State Engineer an appointive or elective officer, the meeting adjourned.

J. S. KEERL, Secretary.

FEBRUARY 28th, 1891:—An adjourned meeting was held at 8:30 P. M., at the office of Messrs. Sizer & Keerl, Helena.

In the absence of presiding officers, Mr. W. A. Haven was elected Chairman.

There were present Messrs. Foss, Wheeler, McRae, Kelley and Keerl.

The minutes of the Fourth Annual Meeting were read and approved. The minutes of the Special Meeting of February 14, 1891, were approved as changed.

Applications for membership were read and filed from Chas. W. Goodale, of Butte, J. S. Bouscaren, of Choteau, and H. P. Rolfe, of Great Falls.

The following report was submitted and read.

HELENA, Mont., Feb. 21, 1891.

To the Montana Society of Civil Engineers:

The undersigned, the Committee to whom was referred the subject for which the special meeting of the 14th inst. was called, reports as follows.

That it is inexpedient for the Montana Society of Civil Engineers to memorialize or petition the Legislature at the present session, to create the office of State Engineer; that there does not appear to be any immediate or pressing need for such an office, which, if created and properly filled, would entail upon the State for salaries of the engineer and assistants, clerks, rents and expenses, at least twenty thousand dollars per annum; that it would tend to degrade the Montana Society of

Civil Engineers, as a scientific body, in the estimation of the public for it to ask the Legislature to create a new department in the State government, or an office to be filled almost entirely by its members or those who may become such; that without doubt the time will come, in a few years, when the various public works of the State will necessitate the supervision of some such an officer as State Engineer, but that the demand for the creation of the office should come from the people at large, and that this Society should then be ready to advise with the Legislature as to the details of the Creating Act, to the end that the State should have the office filled by one worthy the name of "Engineer."

That in the meantime a committee should be appointed by the Society to collect in every practicable way full data as to the office of State Engineer, in all the states between the Mississippi River and the Pacific Ocean, to ascertain his duties, responsibilities, mode of election or appointment, the salary or emoluments, etc., etc.,—that this committee should make frequent reports to the Society in order that every member thereof should have an opportunity to express his views, that the subject should be thoroughly discussed, as far as possible in writing; that these discussions and the final report of the committee and the action of the Society thereon should be published in the newspapers in every county of the State, so as to inform the people on the subject and to create and guide public opinion as to the desirability of creating a "Department of Public Works" with a State Engineer to be elected by the people at the head of it. That if this committee is appointed and continued for two years as a working committee, the next Legislature could take up the subject with widespread knowledge of what the people want of them in this matter. Your committee therefore submits the following resolution for your consideration.

W. A. HAVEN, Committee.

Resolved, That the President of this Society be requested to appoint a special committee of three members to investigate and to consider the subject of the creation by the Legislature of Montana, of the office of State Engineer, or of a department of Public Works, with a civil engineer as one of its board of managers; that this committee be empowered to collect from whatever source they see fit, all data as to the office of State Engineer, or any similar office in any of the states, particularly those between the Mississippi River and the Pacific Ocean, as to their duties, responsibilities, jurisdiction, salary, perquisites, assistants, manner of election or appointment, etc., etc.; also as to what public works in the various states, and particularly what public works in the State of Montana, require the supervision of a State Engineer—that this committee shall be reimbursed for the necessary expenses of postage, stationery, typewriting and printing; that the committee shall submit reports of their progress to the Society whenever called upon to do so by the President, or the Society at any meeting.

The recommendations of the report were discussed and upon motion carried; the resolution as submitted was adopted.

The Secretary submitted and read the following:

HELENA, MONTANA, January 17, 1891.

To the President and Members of the Montana Society of Civil Engineers:

GENTLEMEN:—In compliance with your instructions of this date, I present the following statement from the Secretary's books, showing receipts and disbursements covering the period from January 18, 1890, to the date of my appointment as Acting Secretary, May 31, 1890:

RECEIPTS.

From dues and initiation fees	$76.00
Vouchers are here attached showing this amount as having been paid to the Treasurer.	

EXPENDITURES.

For assessment account Association Engineering Societies	$ 55.25
For part traveling expenses of Representative, account Board of Managers, Association of Engineering Societies	30.00
For printing and stationery	57.50
For clerical assistance tendered Secretary	27.82
	$170.57

RECAPITULATION.

Total receipts for the year 1890	$ 410.50
Total expenditures for the year 1890	117.47

I have the honor to be, your obedient servant,

J. S. KEERL, Secretary.

The Secretary reported that the original of this supplemental report was in the hands of the Board of Trustees and attached to his report.

The following standing committees were named for the current year: "Topics," "Library" and "National Public Works."

The committee on Revision of the Constitution and By-Laws was instructed to make a report at the next regular meeting.

The Secretary was authorized to draw an order upon the Treasurer to pay the balance due on account of the annual banquet.

The Secretary was directed to send statements to members showing their indebtedness to the Society, and to include therein the dues for the current year.

A number of communications were read and ordered filed.

Adjourned. J. S. KEERL, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

JANUARY 13TH, 1891.—Club called to order at 8 p. m. Vice-President Gobeille in the chair. C. M. Barber was elected Secretary pro tem.

The minutes of the last meeting were read and approved. Mr. Chas. W. Wason was elected an active member. The name of C. M. Barber was added to the committee on New Quarters. On motion by Prof. Howe, the rules were suspended and Mr. C. P. Leland read a paper entitled "Annual Reports," which was full of interest and valuable information. After the reading of the paper the regular order of business was resumed. The Chair appointed two committees on Nomination of Officers for the ensuing year which were as follows: 1st committee, John Whitelaw, F. S. Barnum and H. C. Thompson. 2d committee, Prof. E. W. Morley, C. H. Strong and W. R. Warner.

Mr. C. M. Barber introduced the subject of a new constitution, and presented to the Club a constitution which had been prepared by Pres. W. H. Searles. It was stated that Pres. Searles had spent a great deal of care and labor upon this work and it was regretted that he could not himself present it to the Club. The constitution was then read. On motion by Mr. Goebeille (Mr. Swasey in the chair) it was agreed that the Club should hold an adjourned meeting in two weeks for the purpose of discussing the constitution.

Prof. C. H. Benjamin then read a very interesting paper entitled, "Methods of Ascertaining the Cost of Manufacture."

The Secretary announced that the Club had received from Mr. John C. Trautwine a copy of his valuable book on engineering.

It was announced that President W. H. Searles had presented to the Club several valuable articles, formerly the property of the Antimetric Society, and a list of the articles was then read.

On motion by Mr. Baker the thanks of the Club were extended to Mr. Trautwine and Pres. Searles.

Adjourned. C. M. BARBER, Sec'y, pro tem.

FEBRUARY 10TH, 1891.—Club met at 8 p. m. Vice-Pres. Gobeille in the chair and 17 members and 2 visitors present.

The minutes of the last meeting were read and approved.

Prof. Frank Howard Neff was elected to active membership.

The Executive Board reported Mr. C. H. Burgess to the Club for election to active membership.

Mr. Whitelaw from one committee on Nominations reported the following list of candidates for office for the ensuing year:

President, B. F. Morse; Vice-President, C. S. Howe; Secretary, A. H. Porter; Corresponding Secretary, S. J. Baker; Treasurer, N. P. Bowler; Librarian, C. M Barber; Members of the Board of Managers, Pres. Cady Staley, Prof. W. Morley.

Mr. C. H. Strong from the other committee reported:

President, Jos. Leon Gobeille; Vice-President, M. E. Rawson; Secretary, A. H. Porter; Corresponding Secretary, F. C. Osborn; Treasurer, N. P. Bowler; Librarian, C. M. Barber; Members of the Board of Managers, Pres. Cady Staley, S. J. Baker.

The subject of the annual banquet was brought up and received some attention. Mr. Whitelaw moved that the price of the tickets should not exceed two dollars each. This motion was carried unanimously.

Motion was made and carried that the Chair appoint a committee on banquet of seven members and that the Vice-President also be a member of the committee, and that the date for holding the banquet be as nearly as practicable one week after the annual meeting.

The Chair appointed as Committee on Banquet: A H. Porter, Chairman; C. M. Barber, C. P. Leland, A. Swasey, C. S. Howe, H. B. Strong, W. L. Otis.

Mr. M. W. Kingsley then read an interesting paper upon "Notes and Surveys on the Cleveland Waterworks Tunnels."

Mr. Kingsley exhibited a map showing the original location of the tunnel and the location as finally built.

He described the method of location, the difficulties from obstructions and quicksands encountered during the progress of the work, and the accuracy with which measured distances and heights compared with those obtained from calculation. The map also showed the location and soundings for the proposed extension of the tunnel two miles further into the lake.

After the conclusion of the paper there was a discussion in which a number of members took part.

Adjourned. A. H. PORTER, Sec'y.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

FEBRUARY 2ND, 1891.—Regular meeting of the Society was held in Parlor 4, Hotel Ryan at 8:30 p. m., Feb. 2, directly following the entertainment of the Minneapolis C. E. Society at dinner.

Present, 18 members of the Minneapolis Society and 15 members of the St. Paul Society.

President Mason read an address of welcome to our visitors. Minutes of the previous meeting dispensed with. Applications for membership from Chas. F. Hollingsworth and John B. Hawley were presented for ballot at next meeting.

The President named Messrs. Rundlett, C. W. Johnson and Loweth as the examining board for the ensuing year.

Mr. Morris' nomination of Messrs. A. Johnson, Rundlett and Powell as a committee to draw a memorial to our late associate, Mr. J. Lathrop Gillespie, was approved and on motion the Secretary was directed to accept the gift of 28 volumes presented to the Society by Bishop Geo. D. Gillespie, Executor.

Mr. Van Duzer, of the Minneapolis Society then read a paper on Sewer Construction in Minneapolis. He illustrated the general plan of the system, recited its history and dwelt on interesting details of construction.

Minneapolis now has 80 miles of sewers, 20 miles of which were built the past year and wholly by day labor. 97 per cent. of the total mileage is the work of the last decade. Intercepting sewers dispose of a goodly volume of the storm waters and all sewers are copiously flushed automatically.

Mr. Munster's paper of last month on a short method to results obtained by Gordon's formula, was then quite generally discussed, several members having tested the diagram based on his simplified formula, pronounced the results practically correct and endorsed the method.

Immediately previous to adjournment announcement was made that the second

of the four proposed joint meetings of the two societies would be held in Minneapolis probably on the first Thursday in March.

Adjourned. C. L. ANNAN, Sec'y.

MARCH 2ND, 1891. Regular meeting March 2, was held at Hotel Ryan at 8:30 p. m. President Mason in the chair. Present, seven members.

Mr. Munster of the committee of General Arrangements reported that permission had been granted the Society to occupy one of the rooms on the upper floor of the Court House, and offered several suggestions for the evening's consideration. He incidentally stated that the library had been increased by sixty-three volumes in the last two months.

Report accepted and on motion the committee (Messrs. Munster, Woodman and Powell) was continued with power to select room and furnish the same at its discretion in time for use at the next regular meeting, the necessary money to be raised by subscription.

Treasurer's report for 1890 read and accepted.

The Librarian was authorized to subscribe for one year for *Engineering News*, the *Engineering Record*, one English, one French and one German engineering periodical.

The President, Secretary and Treasurer as a committee were empowered to make a resident and non-resident division of the membership list with a view to adjusting dues.

John B. Hawley and C. F. Hollingsworth were unanimously elected to membership.

Adjourned. C. L. ANNAN, Sec'y.

ENGINEERS' CLUB OF MINNEAPOLIS.

ANNUAL MEETING, JAN. 15, 1891.—The Club met at the Public Library at 8 p m. President William A. Pike in the chair and sixteen (16) members present. President Pike reported that arrangements had been made with the Society of Civil Engineers of St. Paul to hold a joint meeting at the Ryan Hotel, St Paul, February 2. Minneapolis to furnish the paper, which will be by Mr. W. D. Van Duzee, on the History of the Sewerage of Minneapolis. The second joint meeting to take place in Minneapolis, March 5.

On motion a committee consisting of F. W. Cappelen, Chas. O. Huntress and T. P. A. Howe, was appointed to make proper arrangements for the entertainment of the St Paul Club in Minneapolis.

The Secretary reported that since the re-organization of the Club in May, 1890, the following meetings had taken place, and the following papers had been read, viz :—

June 15th, at the Public Library, paper on Ventilation of Public School Buildings, by W. S. Pardee. July 17th, at the Public Library, Efflorescense on Brick, by Prof. W. A. Pike. Report on trip to Cresson to the annual convention A. S. C. E., by Prof. Wm. A. Pike. August 21st, Public Library, committee appointed to attend the meeting on International Congress of Engineers, called by the Western Society of Engineers at Chicago; general discussion of engineering topics. September 18th, Public Library, Estimating of Iron Highway Bridges, by F. W. Cappelen. October 9th, Public Library, Sewer Construction, by S. W. Sublette. November 13th, Guaranty Loan Building. Geodetical Survey of Minnesota, by Prof. W. R. Hoag. Afterwards banquet. December 11th, Public Library, On Special Assessments of Public Improvements in the City of Minneapolis, by Chas. O. Huntress.

The Secretary further reported $26.78 on hand.

The following officers were elected: President, Wm. A. Pike; Vice-President, T. P. A. Howe; Secretary and Treasurer, F. W. Cappelen; Librarian, A. B Coe; Member Board of Managers Association Engineering Societies, Andrew Rinker.

Adjourned. F. W. CAPPELEN, Sec'y. and Treas.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JANUARY 21, 1891.—A regular meeting was held at the American House, Hanover street, Boston, at 20 o'clock. Vice-President McClintock in the chair. Forty-two members and twelve visitors present.

The record of the last meeting was read and approved.

Mr. Gilbert Hodges was elected a member of the Society.

On motion of Mr. Stearns it was voted to elect from the floor a committee of three to report the names of the committee to nominate officers for the ensuing year. The committee elected was Messrs. F. P. Stearns, C. W. Folsom and Sidney Smith. Later in the meeting the committee reported the following names: Desmond Fitzgerald, L. B. Bidwell, J. A. Gould, Jr., Dwight Porter and H. L. Eaton, and they were unanimously chosen as the nominating committee.

Mr. Frank P. Johnson described some devices which he had found useful in carrying on survey work with as much rapidity as possible at small cash outlay, still holding fast to accuracy.

He said:—First you will notice the means of getting there which you will see is a tandem tricycle rigged to carry the instrument, rods, etc., as well as two men. Apart from the cost of experiments with other arrangements which did not prove altogether practicable, the special additions here exhibited cost about three ($3.00) dollars. Two men can drive the wheel, loaded as shown, with much less fatigue than walking the same distance would occasion and at a speed as good as the average horse would make. Mud does not particularly bother, but sand is discouraging.

This transit rod with wire legs tripod attachment was designed for use on frozen ground or on a point coming on ledge or a large stone, etc. I find it particularly handy where it is desirable to sight back repeatedly from different positions as at a point or for fishing in an intermediate point on a line when one end can not be seen from the other. It may be readily placed and, once set, is always ready to be sighted at from any direction and does not have to be whistled up to its work just as one is ready for a sight after some chance delay. I use a piece of ½in. painted gas piping seven feet long, with a steel point welded into one end. A rather loose brass collar with three legs radiating from the sides serves to connect the wire legs of the tripod with the rod proper. This plays up and down the rod as desired, and is clamped where wanted by a thumbscrew piercing one side and impinging against the rod. Any blacksmith can make it.

Perhaps the most useful rod I have struck is this combination, leveling stadia and transit rod, 14.4 feet long when spliced and 7.2 feet when folded for transportation, the style of joint being such that no ungraduated wood is carried and there is no lessening of strength or working loose at the joint, while the alignment is continuous throughout. I may say in passing that this jointing of the pieces has cost about as much trouble as all the rest of the rod. I have abandoned five or six styles of hinge and splice joints as not meeting the requirements. For stadia and leveling work alternate tenths are painted red and white; every other tenth is numbered with a number one-tenth high, top of number top of tenth; the hundredths are indicated by saw teeth (the middle tooth longer than the rest), thousandths are estimated by the eye. The foot is marked by a number a tenth and a half high. For the sake of staunchness and to avoid warping I have the stick 2½x1¼ inches.

One edge is painted for transit rod use and in order to keep so long a rod plumb for close work, I have designed an adjustable bubble which will screw on the side of the rod. One is affixed to each of two sides of the rod and set for vertical position of the transit painting. If at any time one becomes knocked out of adjustment it is easy to loosen the two upper screws that hold the rod vertically and then tighten the screws again as soon as the bubble has been pushed to correct position. When in use as a transit rod its length makes it a wonderful time saver, particularly in passing obstructions or over hills or on difficult sights among brush and leaves. Being provided with bubbles the greenest hand can use it after five minutes practice, thus permitting first-class results being secured with third-class help and that too very expeditiously.

Mr. Lawrence Bradford read a paper on the Upper Missouri river, describing the course from Bismark to Fort Benton at the head of navigation, a distance of 1,000 miles, showing the marked characteristics of the river and of the scenery. The works of the government for the improvement of its navigation were particularly described, reaching for about 120 miles down from Fort Benton. The work consisted of dams for the contraction of the channel and the clearing of the stream from bowlders so that a minimum depth might be obtained of three feet as the lowest stage of the river. Mr. Bradford showed that the traffic of the river was considerable after 1860, to supply the Canadian trade and that of the mines of Montana and Idaho, but that the construction of the Canadian and Northern Pacific Railways, and later the St. Paul, Minneapolis & Montana Railroad, have made it no longer profitable to ship goods up the river.

Adjourned. S. E. TINKHAM, Secretary.

FEBRUARY 18TH, 1891:—A regular meeting was held at the American House, Boston, at 19:45 o'clock. Vice-President Freeman in the chair. Seventy-two members and twelve visitors present.

The record of the last meeting was read and approved.

Messrs. John T. Desmond, Eugene E. Pierce, Frank B. Sanborn, Caleb M. Saville and Howard C. Slater were elected members of the Society.

Mr. Henry Manley was appointed a committee, with full powers, to make the arrangements for the annual dinner. The sum of $50 was appropriated to meet the incidental expenses of the dinner. Mr. Manley asked for an expression from the meeting as to the date preferred for the dinner. Tuesday, March 10th, was selected.

Attention was called to the death of Richard Fobes, a member of the Society, and on motion of Mr. Howe the chair was requested to appoint a committee to prepare a memoir. Messrs. C. A. Allen and L. A. Taylor were appointed as the committee.

On motion of Mr. Brooks it was voted to extend the hearty thanks of the Society to Hon. S. B. Stebbins, Chairman of Commissioners on New Court House, for courtesies shown the members on the occasion of the visit to the New Court House.

The Secretary read a paper prepared by Mr. E. W. F. Natter, describing the different methods used by the United States Geological Survey in surveying the State of Massachusetts in the years 1884 to 1888, and also a general history of former surveys.

Mr. Louis F. Cutter followed with an account of the plane-table and barometric work done by him on the same survey in 1886, and gave in detail the cost of his work.

A general discussion followed upon the new map of the State of Massachusetts, in which Messrs. Chaplin, Stearns, Tidd, Hodgden, Brooks, FitzGerald and McClintock, took part.

After passing a vote of thanks to Mr. Natter for his kindness in preparing his paper the Society adjourned.

S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

341ST MEETING, FEBRUARY 4TH, 1891:—The 341st meeting of the club was held at 8:15 P. M., February 4, 1891, in the club rooms, Vice-President Eayrs in the chair, and twenty-nine members and one visitor present. The minutes of the 340th meeting were read and approved. The executive committee reported the doings of its 103d meeting. The applications of Messrs. Faris and Molitor for membership in the club were approved. Upon vote by the club Messrs. Faris and Molitor were duly elected.

Col. E. D. Meier reported for the Whitman ibrary committee, that, aftei investigation, they would advise the purchase by subscription of the libray; about $700 had already been subscribed for this purpose. The report was accepted and the committee continued to take charge of the subscriptions.

Prof. Johnson reported the receipt of six volumes for the library, presented by Mr. Leonard, and one volume presented by Prof. Howe. Moved that the thanks of the club be extended to Mr. Leonard and Prof. Howe.

The paper for the evening on "Some Experiments to Determine the Strength of American Vitrified Sewer Pipe," by Prof. M. A. Howe, was then read: In looking for data concerning the strength of vitrified sewer pipe, no results were found of any systematic tests of pipe made by different manufacturers. In order that such data might be available, the following experiments were made in the testing laboratories of the Rose Polytechnic Institute: 1. The hydraulic test, to determine what load of water would burst the pipe, and also the tensile strength of the material. 2. The drop test, to ascertain the behavior of the pipe when subjected to "percussion action." 3. The concentrated load test, to determine the maximum load a length of pipe would sustain at its center when supported at both ends. 4. The uniform load test, to determine the maximum pressure the pipe would stand when surrounded by sand uniformly loaded. 5. The cement joint test, to determine the strength of cement joints.

Three methods were employed in making the hydraulic tests. In two of the methods the pipe was subjected to an end pressure, and the results were found to be unreliable. In the third method the pipes were not subjected to end pressures, and much more uniform results were obtained. From an average of about 140 results the average strength of the material composing the pipe was found to be about 600 pounds per square inch.

The drop test consisted of dropping a weight of eighteen pounds upon the center of the pipe which was supported at the ends. The results indicated that the pipe should not break when subjected to ordinary jars or blows.

The concentrated load test consisted of applying, slowly, with a hydraulic press, a load at the center of the pipe which was supported at both ends. With hardly an exception the pipes tested supported 2,000 pounds without cracking.

The uniform load test was similar to the concentrated load test, only the pipe was surrounded by sand and a uniform pressure applied to the surface of the sand. In no case was a piece of pipe collapsed, although a load of 16 tons was applied to the surface of the sand in a space of 12×18 inches.

In the cement joint tests the apparatus used in the hydraulic tests were employed. Usually, when the water did not get between threads of the pipes, the joint held until the pipes failed, but when watei did get between the ends of the pipes, the cement joints failed at once. Each make of pipe was found to have a color which corresponded to the greatest strength and also a peculiar ring by which the strong pipes could be selected.

Discussion followed by Messrs. Johnson, Moore, McMath and Meier.

Moved that the thanks of the club be extended to Prof. Howe for his very able and interesting paper.

For the next meeting a paper on "Specifications and What Should be in Them," by Prof. J. R. Kinealy, was announced.

Adjourned. ARTHUR THACHER, Secretary.

342ND MEETING, FEBRUARY 18TH, 1891:—The 242nd meeting of the club was held at 8:20 P. M., February 18, 1891, in the club rooms, President Burnet in the chair, and twenty-six members and one visitor present. The minutes of the 341st meeting were read and approved. The executive committee reported the doings of its 104th meeting.

Prof. Johnson made the following motion, which was carried: That a committee be appointed to report to the club the advisability of obtaining portraits for the club of Capt. J. B. Eads, Thos. J. Whitman and C. Shaler Smith. The following committee was appointed: Prof. Johnson, M. L. Holman, G. H. Pegram.

Applications for membership were received from A. J. O'Reilly and J. O. Walker, and were, under the rules, laid over for action by the executive committee.

The paper of the evening on "Specifications, and What Should be in Them," by Prof. J. H Kinealy, was then read by Prof. Gale. The paper dwelt upon the difficulties of properly stating the quality of material to be used in construction, owto the lack of definite standard tests for most building material. Owing to this lack of standards it was too often the custom to call for a certain brand or make. This necessarily narrows competition, and was not done because this brand or make was necessarily better than its competitors, but because the writer of the specifications was familiar with this brand and had no standard tests to determine the quality of the material offered. Under these conditions, it seemed desirable that efforts should be made to obtain some standard tests for the materials to be used. Other specifications are faulty from a lack of knowledge of details, and it is often left to the bidder or contractor to determine what is called for, the specifications simply stating that certain things shall be done whenever necessary. This lack of definiteness leaves much to the contractor, and the bids are often on very different things, one contractor calculating to use very much better material than another. As contracts are generally let to the lowest bidder, this is apt to place the contract with the bidder who has taken advantage of the looseness of the specifications and has bid on the smallest amount and cheapest material.

Discussion followed by Messrs. Johnson, Holman, Burnet, Long, Seddon, Farnham and Crosby.

Mr. F. E. Turneaure then presented a short paper on "A Simple, Graphical Method for Determining Moment of Inertia." This is a general method for determining the moment of inertia of an area about an axis, and is especially useful where the moment of inertia is required of the cross sections of rails or beams of irregular form, or of sections formed of disconnected parts. In the case where the axis is given in position, it consists essentially in the measurement of a new area which is easily constructed, having first the given area drawn to scale. The required moment of inertia is then equal to this new area multiplied by the square of a length, which length may be chosen at will. With the aid of a planimeter this method is quite rapid and accurate as well. The demonstration of the correctness of the method was then given. The paper also contained the demonstration of a similar method for finding the moment of inertia about an axis through the center of gravity, whose position is not known.

A paper on "Brick-Making Machinery," by N. W. Perkins, Jr., was announced for the next meeting.

Adjourned. ARTHUR THACHER, Secretary.

343RD MEETING, MARCH 4TH, 1891:—The club met at 8.15 P. M., in the club rooms. In the absence of the President and Vice-President, Prof. Nipher was elected chairman *pro tem.* Twenty-seven members and three visitors were present. The minutes of the 342nd meeting were read and approved. The executive committee reported the doings of its 105th meeting.

Messrs. A. J. O'Reilly and I. O. Walker were elected members.

Mr. Guido Panteloni was proposed as a member.

Prof. Johnson reported for the committee appointed at the last meeting in favor of purchasing the portraits of Capt. J. B. Eads and C. Shaler Smith, the portrait of Thos. J. Whitman having been already promised as a donation to the club. The report was accepted and the committee requested to purchase the portraits.

Resolutions were passed that the secretary write to Mr. A. J. Chaphe, asking that the club be allowed to again enroll his name as a member.

Mr. S. Bent Russell presented a memoir on the late Samuel Forder Burnet.

Mr. N. W. Perkins, Jr., then read the paper of the evening on "Brick-Making Machinery." The paper briefly sketched the history of brick making, and then dwelt in detail on the machines now being used and constructed. Full discussion followed by Messrs. Holman, Wheeler, Seddon, Perkins. Bruner, Johnson and Flad.

Mr. Johnson announced the presentation by Messrs. Anderson and Barr of a copy of "The Washington Bridge." Moved that a vote of thanks be given to Messrs. Anderson and Barr.

Adjourned.

ARTHUR THACHER, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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AN ENLARGED WATERWAY BETWEEN THE GREAT LAKES AND THE ATLANTIC SEABOARD.

By E. L. Corthell, Member Western Society of Engineers.

Abstract of a Paper read before the Canadian Society of Civil Engineers, Feb. 12, 1891, by Mr. Corthell, also a member of that Society.

[Read April 8, 1891.]

The object of the paper is to state and discuss the question of the practicability of making an enlarged waterway from the Northwest to the Atlantic seaboard and Europe. An enlarged waterway having reference to the Great Lakes is one adapted adequately to the largest freight carriers of the lakes. The capacity of these freight carriers is assumed to be not less than 3,000 tons of cargo and whose displacement weight shall not be when laden, less than 5,000 net tons with a draught of 20 feet. All canals and channels, and projects for the same, that are evidently not equal to these requirements are immediately eliminated from the discussion.

The history of railroads, barge canals and ship canals and of unrestricted waterways, teaches that none but channels of the largest dimensions can compete with the economy, speed and other numerous advantages of rail transportation, particularly in the United States and Canada.

For nearly 30 years, almost from the inception of the development of the West, efforts have been continually made by commercial men to bring the project of an enlarged waterway to a realization but thus far without success.

As long ago as 1865 an able advocate of this waterway enlargement asked the question, in a public document, "Why should the lake cities with their wealth and resources not import for themselves and transact their own business? The ocean is the prerogative of no State of the Union, and the West will seek the channel which conducts its commerce with the least cost and delay." If there was force in this remark in 1865 there certainly is a greater force at the present time. If there had been one country only between Chicago and the seaboard along the natural lines of the waterway leading from the Great Lakes, there would have been

built no doubt years ago adequate channels following the course of the St. Lawrence river.

Between Chicago, Milwaukee, Duluth and other ports of the more western lakes and Liverpool there are over 4,000 miles of water navigation, 71 of which only are restricted by obstacles in the channels. Therefore the object of this paper is to ascertain if these natural obstacles can be removed and whether steamships on the Great Lakes may not be able to ply between these ports and the ports of the Old World.

The scope of a paper discussing subjects of this importance and extent is a broad one. The entire situation must be canvassed and other than engineering features must be brought into the discussion. We are led at once into an important commercial investigation. The important relations which the railroad system of the country bears to this question must be carefully considered. The subject is therefore discussed on the following lines:

1st. Its historical features showing the development of commerce and the increase in capacity of the channel-ways demanded by this commerce.

2nd. The physical conditions of the present and proposed routes.

3rd. A brief statement of the financial and political questions involved.

4th. The commercial features, and results.

As a matter of general interest and introductory of the details of the subject, the recent geological changes that have taken place in the drainage of the North American continent are briefly sketched, and there is also given an historical sketch as well as an engineering statement of the combined waterway and sewage channel now being constructed by the city of Chicago between Lake Michigan and the Illinois river. The effect of this channel (depleting the lake of quite a large volume of water) upon the levels of the lakes is discussed as being a question of some international importance. The result of the discussion is that we can dismiss any fears that now exist in regard to the deleterious effects of this channel-way upon the harbors and the connecting waterways of the lakes.

The vast water spaces of the Great Lakes, their length, breadth and depth are briefly described and the main facts stated.

The historical features of the various canals and channels now existing are stated.

St. Mary's Fall Canal between Lakes Superior and Huron.

This canal was opened in 1855 with two locks 220′ long and 70′ wide—12′ deep. These dimensions have been increased from time to time. The lock now being built by the U. S. government is 800′ long, 100′ wide, with 21′ of water on the mitre sills, and at a cost of nearly $5,000,000.

St. Clair River Improvements.

The St. Clair River improvements between Lake Huron and Lake St. Clair show also an increasing depth and width of channel. This work has also been done by the U. S. government. In 1866 it was made 13′ deep, 300′ wide and protected by timber dikes. The project under way contemplates a depth of 20′. The Lime Kiln Crossing at the mouth of the

Detroit river has much the same history as to its increased size. The depth has been increased from $9\frac{1}{2}'$ in 1858 to 20′ in 1890.

Welland Canal.

A brief history of the Welland Canal is given. The first project was that of 1824 for building a canal and railroad combined, the work having been begun at that time with wooden locks 110′ long, 22′ wide and 8′ deep. Water was let into the canal in 1829 and two vessels went through in that year. The dimensions of this canal have never kept pace with the size of vessels navigating the lakes. The present locks are 270′ long, 45′ wide with 14′ depth of water. Up to the present time or to 1889 there has been expended on this work according to official reports, $23,787,950.30.

Trent River Navigation.

The Trent river navigation, which is brought into the paper for the reason that it is navigated. though by an inferior class of navigation, consists of a series of canals with intermediate stretches of rivers and lakes with a depth of 5′ or 6′. It extends from Trenton at the mouth of the Trent river on Lake Ontario to Lake Huron. The entire length of the route is 201 miles. Its total lockage 1,044′. It is at once apparent that it would be impracticable to improve this circuitous route over an undulating country so as to make of it a ship canal of adequate dimensions.

The St. Lawrence River Improvements.

One of the most important improvements in the line of what is certain to become an enlarged waterway between the lakes and the seaboard is the deepening of the shallow reaches of the St. Lawrence river between Lake Ontario and its mouth. From Montreal to the sea a depth of 27′ to 30′, and of sufficient width, has been obtained by dredging through the shallows which here and there interrupted the greater depths of the river. But the most serious obstacles in the St. Lawrence are above Montreal where frequently the river flows over a rocky bed in the shape of rapids. These rapids have been flanked by canals. They are the Beauharnois, Cornwall, Farran's Point, Rapide Plat and Galop. Their combined length is $43\frac{1}{4}$ miles. The original depths designed by these canals when they were inaugurated in 1841, was 9′. but this depth has never been maintained on account ot the fluctuations in the river. At times it falls to 6′ 7″. In 1871 on account of the increasing size of vessels, barges and boats, it was decided by the government to make a navigable depth of 12′ through all the canals and the river shallows, and soon after that a 14′ depth was decided upon. Work since that time has been carried on with this object in view, the standard dimensions of the locks being, length 270′ width 45′ and a clear depth of 14′ on the mitre sills. This work has not been, as yet. completed but, for the purposes of this paper, the work is assumed to be entirely performed. It may be stated in round numbers that the entire amount expended on the St. Lawrence system from Lake Erie to Montreal is about $41\frac{1}{4}$ million dollars and that, to finish the work now in hand, it will cost about $12\frac{3}{4}$ millions more. or say, $54,000,000 in

all. This does not include the construction of a canal at the St. Mary's Falls between Superior and Huron and some other necessary improvements. It may therefore be stated that in obtaining, between Lake Superior and Montreal, a full depth of 14′ it will have cost, all told, about $60,000,000.

Erie and Oswego Canals.

Between Buffalo and Oswego and the Hudson river at Albany there exists one of the most important means of transportation, so far as the past history of transportation in this country is concerned. This is the Erie and Oswego canals. On the Erie Canal there are 71 locks 7′ deep, 110′ long, 18′ wide with a total lockage of 657′. The Oswego Canal is 38 miles in length and has 18 locks. The entire expenditure on these canals up to 1886 had been $133,000,000 expended by the State of New York.

Lake Champlain and Hudson River.

Another route which has been of service as a barge canal extends from the St. Lawrence river 46 miles below Montreal, up the Richelieu river to Lake Champlain and thence up Lake Champlain and from this lake to the Hudson river. 81 miles of this canal is in Canada. The total distence is 265 miles, 7 miles of which is by the Erie canal. The canal is generally of very moderate proportions being about 36′ wide at the bottom with 7′ of water on the sills.

Railroads.

One of the most important factors in transportation during the last half century has been the railroad. This method has become so nearly perfect and the cost of transportation by it so greatly reduced that it is able not only to compete successfully with barge canals, but in many cases with transportation on large rivers. In various parts of the United States the successful competition of the railroad with the canals has led to the abandonment of the latter and where the canal does exist it is generally maintained by taxing the public at large for its expenses. No one wishes to depreciate the immense value which this former means of transportation has been to the country, but we are compelled to state that a better method has come to supersede it and that the only possible means of competing with this better method is to make one better still.

An idea of the immense business performed by the railroads and of their extraordinary growth will appear from the following facts: In the year 1840 there were in the country tributary to the Great Lakes only 89 miles of railroad. In 1850, 1,276 miles; in 1860, 10,238; in 1880, 37,456; in 1889, 63,688, and in that year these railroads moved over 208,000,000 tons of freight. These railroads are in the United States. There are over 8,000 miles more in Canada. The railroads with their advanced methods and improved facilities for transportation have built up great centers of population and trade which lie directly along what may be made a continuous and adequate waterway to the seaboard.

The immense railroad business transacted at Chicago, one of the ports on the Great Lakes, will be seen from the following:

Length of main lines of railroad terminating at this city is.. 54,411 miles
The number of freight cars received and forwarded in 1889.... 4,248,769
The number of tons of freight received and forwarded....... 43,013,444

HARBORS.

In reference to the harbors of the lakes, the United States government has expended large sums of money in deepening, improving and protecting them and has begun a system of improvements of equal capacity to the channels between the lakes. Its present policy is to improve these harbors to a depth of 20′. The average depth at present in the harbors of the larger ports is 16′.

The most important historical feature of the subject is the growth of commerce on the lakes.

1st. In respect to the size of vessels.

2nd. The tonnage carried.

In 1859, 36 of the largest lake propellers averaged about 700 tons register, ranging from 583 tons to 981, with a maximum draught, when fully laden, of 11½′. The history of the increase in size of vessels is a most interesting one but the limits of the paper do not permit of this history being traced. But it may be stated that in 1890 the business fleet of the lakes consisted of 2,055 vessels aggregating 826,360 net register tons, the total value being $58,125,500. 232 of these vessels are steamers of over 1,000 tons register, 110 of them are over 1,500 tons and many of them are from 1,600 to over 2,100 tons, and with a carrying capacity of from 3,000 to 3,700 cargo tons. The draught of these vessels is limited by the depths of the channels and harbors, but many of them could safely and profitably load to 19 or 20 ft. The recent growth ot lake commerce is extraordinary and it is difficult to predict the amount of tonnage upon the lakes and the size of the vessels before the end of the present decade. In 1886 the total valuation of the vessels was about $30,500,000. In 1890, as has been stated, over $58,000,000 and the number of steamers in the same time of over 1,500 net register tons has increased from 21 to 110.

At the St. Mary's Falls Canal where careful records are kept by the government officials the increase of commerce is clearly noted. In 1870 the entire amount passing through this canal was 690,826 register tons. In 1880, 1,734,800. In 1883, 2,042,259. In 1887, 4,897,598. In 1890, 8,454,435 and the actual weight of cargo carried in that year was 9,041,213 net tons. The value of the tonnage has increased from about $29,000,000 in 1881, to over $102,000,000 in 1890. The amount of commerce on the Great Lakes will very favorably compare with the foreign and coast-wise commerce of the United States. The tonnage through the St. Mary's Falls Canal is greater than that through the Suez Canal.

While the lake business has thus rapidly increased the waterways east of Lake Erie have hardly maintained their former traffic. This is true of the Erie Canal, the Welland Canal and the St. Lawrence River canals. No doubt that the principal reason for this decline, as it really is, in the business of these artificial waterways is their inadequacy for the business that would otherwise come to them. For instance, the Welland Canal

has 14′ depth of water. According to the United States Bureau of Navigation—report 1889, there were 330 U. S. vessels in the Great Lakes above Niagara Falls which drew too much water, when laden, to go through this canal. Eighty-six of these were sailing vessels and 244 steam vessels, with a total tonnage of 444,192, about one-half of the entire lake tonnage. Of those that passed through this canal in the year 1889 most were U. S. vessels and they were obliged to reduce their cargoes in order to pass through, from a total tonnage, 71,502 to 63,283 tons.

Improved methods of transportation by rail, increase in the size of lake vessels. and their cargoes and, principally, the rapid growth of steam transportation on the lakes and rival competition between various lines of lake vessels and the railroads have compelled continual reductions in the cost of transportation. The records of the business through the St. Mary's Falls Canal show that the cost per ton per mile of carrying freight an average distance of about 800 miles in 1887 was 2.3 mills, and in 1889, 1.5 mills. Careful calculations made by Mr. Charles H. Keep, Secretary of the Lake Carriers' Association, given in a paper addressed to the U. S. Congress, Dec. 5, 1890, show that the value of all the cargoes carried on the lakes the last season was over $305,000,000, the average distance of carriage being 566 miles, or a total of about 15½ billion ton miles. If this had been carried at railroad rates the cost to the public would have been over $143,000,000, but by the prevailing lake rates the cost was only about $23,000,000, so that water transportation on the lakes in one year saved to the public nearly $120,000,000. Much of the heavy freight has been carried for considerably less than 1½ mills per ton mile. Anthracite coal is carried from Buffalo to Duluth a distance of 1,000 miles, for 30 cents per ton, or 3/10 mill per ton mile. The lake rates from Chicago to Buffalo on wheat have been reduced from 11 cents per bushel in 1861 to 2½ cents in 1890. The large steamers with barges in tow can transport grain at 2 cents between Chicago and Buffalo, with a profit.

The increase in population of the lake cities indicates the great increase there must necessarily be in the business of the lakes and also of the railroads tributary to them. The city of Buffalo has increased from about 42,000 in 1850 to 155,000 in 1890. Cleveland, Ohio, from 17,000 in 1860 to 262,000 in 1890. Chicago from 30,000 in 1850 to about 1,100,000 in 1890.

The preceding commercial statements covering nearly three pages of the proof of the detailed paper are so important that the abridgment of them seriously detracts from their effect. They have been compiled from a large amount of detailed information placed in the author's hands through the kindness of the officials of the United States and Canadian governments and by officers of transportation lines and secretaries of boards of trade of the lake cities. The one subject of the growth of the commerce of the Great Lakes with the accompanying reduction in freight rates and a description of the methods of transportation, both by water and rail, would of itself form a most interesting and important paper.

With these facts before us it is necessary to take up the physical conditions now existing of the various present and projected routes to the sea-

board and ascertain if it is practicable to develop within a reasonable cost such a commercial route as the commerce of the Great Lakes requires.

St. Mary's Falls Canal with its lock now being built by the United States government is the only artificial work on the Great Lakes that is fully equal lo the requirements of commerce. Tho lock now being built by the Canadian government is to be limited to 18′, which the author does not consider as sufficient to meet the increasing size of vessels.

OTTAWA SHIP CANAL BETWEEN GEORGIAN BAY AND MONTREAL.

In reference to projected routes the first in order is that of the Ottawa Ship Canal between Georgian Bay and Montreal which has been under discussion by the Canadian government since 1858, when the well known civil engineer, Mr. Walter Shanly, made an examination and report. Two years afterwards a second report on this project was made by Mr. T. C. Clarke, Civil Engineer. Mr. Shanly's project contemplated locks 250′ long, 50′ wide and 10′ deep. His estimate for the entire work was $24,-000,000, the total length being 430 miles and a total lockage of 698′. Mr. Clarke's estimate for a 12′ depth on the mitre sills, with locks 250′ long, 45′ wide was $12,057,680. Mr. Shanly estimated that the difference between a 10′ and a 12′ canal would not be less than $5,000,000, so that on the same basis of depth his canal, in cost compares with that of Mr. Clarke's as $29,000,000 to $12,000,000. However, the projects were on an entirely different basis, Mr. Shanly preferring to cut canals at the sides of rapids but Mr. Clarke preferring to raise the levels of rivers and avoid the rock cuttings.

On the plan of an enlarged waterway proposed by the author with locks 600′ long, 85′ wide, and 20′ deep, with a depth of canal prism of 22′, and with a width of canal in short sections of 150′, and in long sections of 200′, and with 24′ depth in the rivers and in slack water reaches, the cost would be about $83,000,000.

A ship railway has been proposed on this route. In the opinion of the author the course of the river is too tortuous and the cost of removing natural obstructions too great to give this alternative project serious consideration.

GEORGIAN BAY AND TORONTO SHIP CANAL, OR ITS ALTERNATIVE, THE HURON-ONTARIO SHIP-RAILWAY.

Next in order is the Georgian Bay and Toronto Ship-Canal, or its alternative, the Huron-Ontario Ship Railway between the same points.

In 1846 a ship canal project was brought forward by Mr. Kivas Tully, Civil Engineer, of Toronto. In 1851 and 1855 further examinations were made under the auspices of the Board of Trade of Toronto, and at a convention of delegates from Western cities the route was favorably considered. Col. R. B. Mason, of Chicago, was employed as Consulting Engineer. He made an examination of the route in 1855. The estimate for the canal was $22,170,150. Its length was 100 miles, with 50 locks with 12′ on the mitre sills. Very serious difficulties in the way of excavation were found at the summit level where there was for ten miles continuous cutting with an average depth of 90′, and a maximum depth of nearly

200′. A company was incorporated for carrying out the project in 1865. Its charter was amended under the name of the Huron & Ontario Ship Canal Company. The project, however, was never brought to the point of actual work.

In 1881 Mr. James B. Eads, at that time engaged on the project of a ship railway across the American Isthmus, was requested by several Toronto gentlemen to give an opinion as to the feasibility of building a ship railway between Georgian Bay and Lake Ontario. His opinion given after a careful study of the subject, was that it was not only practicable, but that the route furnished one of the most favorable locations for such construction. The length of the ship railway route is 66 miles. Mr. Eads' plan was to build three railway tracks of standard gauge, the rails 110 lbs. per lineal yard, and the capacity of the railway was for vessels of 2,000 tons displacement weight and 14′ draught. The estimated cost was $12,000,000. The author was at that time associated with Mr. Eads and familiar with the plans and estimates. In order to present the subject now in connection with other projects for an enlarged waterway, he considered it of sufficient importance to re-examine the subject and to have a personal examination made of the country by one of his associates, Mr. A. F. Robinson, member of the Western Society of Engineers. The plans and estimates have been reformed on the basis of a ship railway of larger capacity than that contemplated by Mr. Eads, that is, for vessels for a displacement weight of 5,000 tons with a draught of 20′, the railway to be capable of transporting during the navigation season 8,000,000 tons of traffic. The summit to be surmounted is 670′ above the mean level of Lake Ontario. The maximum gradient is 33′ per mile, though, over the larger part of the route, the grades will run 11′ to 14′ per mile. The cost of the railway fully equipped for the kind and amount of traffic contemplated is $15,459,318.09. In the opinion of the author this route and this method of transportation is far superior both in its first cost, and in the cost of transportation to the Ottawa Ship Canal, previously described. The differences and the advantages and disadvantages in comparing the two routes are given at some length in the paper submitted to the Canadian Society.

Welland Canal.

To increase the capacity of the Welland Canal to meet the requirements of the proposed enlarged waterway and enlarge and deepen the present locks and the prism of the canal would cost about $25,000,000.

Niargara Falls Ship Canal.

It has been proposed by the U. S. Government to build a ship canal at Niagara Falls on the United States side of the river. In 1867, by authority of Congress, an examination was made for this canal, contemplating a depth of 14′, with locks 275′×46′. Six routes were examined. In 1888 funds were appropriated by Congress for a second examination for a canal with a capacity of 20′. The data from the previous surveys were used in making the plans. The dimensions were to be, locks 400′ long,

80′ wide, with a depth of 21′. The canal was 25 miles in length with 18 locks at an estimated cost of $23,617,900. A revision of this estimate on the basis of larger locks and a larger canal prism (the project contemplating only 100′ width) and an increase in the price of rock excavation which the author considers advisable, makes the total cost about $35,000,000.

NIAGARA FALLS SHIP RAILWAY.

As an alternative to the ship canal estimates have been made for a ship railway on another route, the length of which is 18½ miles. This would require a maximum grade of 50′; 4¾ miles in length. On the same basis as the plans of the Huron-Ontario Ship Railway and of the same capacity and for the same annual amount of traffic the cost is $10,731,613.71, with a full equipment.

MICHIGAN PENINSULA SHIP CANAL AND SHIP-RAILWAY.

It has been proposed to build a ship canal of the standard dimensions above given across the Michigan Peninsula from Benton Harbor, on Lake Michigan, to near Munroe, near Lake Erie, a distance of about 160 miles. It would require 65 locks and the crossing of 19 railroads. The estimate is $138,405,432. A ship railway across the Peninsula on a somewhat different location will cost about $39,000,000. The height to be surmounted is 475′.

Still another route might be considered both for a ship railway and a ship canal, and that is by way of Grand River at Grand Haven on Lake Michigan through, or near, the city of Grand Rapids, Michigan, to the head waters of the drainage of the Saginaw Bay in Lake Huron. The author has not the data for a careful estimate, but is informed that a depth of 18′ or 20′ can be dredged eastward from Grand Haven and westward from Saginaw Bay, leaving an intermediate stretch of about 80 miles where a ship canal or ship railway could be built. The location and direction of this route is such that it would take commerce almost in a direct line from Chicago to Georgian Bay and thence by the Huron-Ontario Ship Railway into Lake Ontario. No estimate has been made of the cost, either of a ship canal or ship railway by this route.

LAKE CHAMPLAIN ROUTE BY WAY OF THE CAUGHNAWAGA RIVER.

The Lake Champlain route from the St. Lawrence river to the Hudson river has been considered. The estimates made at various times by different engineers, both Canadian and United States, for a 12′ navigation averages about $20,000,000 from the St. Lawrence river to Albany. To build this waterway on the plan of the proposed enlarged waterway with locks of standard dimensions, and to deepen the Hudson river from Albany to Hudson City, and Lake Champlain as well, over long, shallow reaches where there is now sufficient depth of water for 12′, but not for 20′, would cost not far from $50,000,000. For the waterway desired, this project is not considered practicable.

ERIE CANAL AND OSWEGO CANAL ENLARGEMENTS.

To enlarge the Erie Canal, and in this case enlargement means an

ample enlargement of the canal prism for a long distance, that is, between Buffalo and Albany, the cost would probably exceed $250,000,000, and were it ever completed there would still be nothing but a continuous canal where the speed of the vessels would be restricted. The same objections exist in regard to the Oswego Canal enlargement. There has been suggested a ship railway instead of either of the canals. The author considers this impracticable, not only on account of its great cost, but on account also of the natural and artificial obstacles that at points would prevent its construction. The Mohawk Valley is now entirely occupied by two railroads (six main tracks), the Erie Canal, the Mohawk river, at times a turbulent stream, overflowing its banks, and an almost continuous line of cities and towns. These natural and artificial conditions are hemmed in on either side by steep and rugged bluffs of hard rock.

St. Lawrence River Enlargements.

The St. Lawrence river enlargements require careful consideration, for the reason that they form the most available natural route for an enlarged waterway, either to receive the traffic over the Huron-Ontario Ship Railway, or the ship canals, or the ship railways at Niagara Falls and across the Michigan Peninsula. The Canadian Government has furnished the author, by the hands of the Chief Engineer of Canals and from the Department of Public Works, much valuable information. The estimate is based on these data and from the plan of the enlarged waterway and the standard dimensions used in other estimates in this paper. The total cost of giving the full depth everywhere from Lake Ontario to Montreal, assuming that the present canals have been deepened to 14′, is $27,000,000.

Comparison of Commercial Conditions.

A statement of the commercial conditions of the proposed routes is necessary in order to make a comparison between them. These conditions have an important bearing on the general question of location and advantages, and are, therefore, stated in full in the body of the paper. "The sailing distances" are steamer distances, and are compiled from many records, a selection being made from the most reliable. The time per hour forming a basis for the total time on each route, is open to amendment, being in some respects a matter of opinion, but formed from much study of the subject and from definite records of speed under practical and similar conditions.

The cost of transit is made up from the actual average cost on lines now operated on railroads, lake, and ocean and barge and ship canals. As to the speed, time and cost on a ship railway, while there is no actual transportation of this kind in existence, yet, the results of ten years of careful study of the subject on the two principal ship railway projects of the world—the Tehuantepec and Chignecto—are used in this statement. Though made from different conditions and by persons working independently, the results closely agree and may be considered the concensus of the best thought on the subject. The figures, however, await the actual test of practice soon to be applied at the Chignecto Isthmus.

Table of Sailing Distances.

New York to Liverpool	3,440	statute miles.
Boston to Liverpool	3,211	" "
Baltimore to Liverpool	3,891	" "
Montreal to Liverpool	3,225	" "

The all rail distance from Chicago to New York is 913 miles via Pennsylvania railroad; 949 miles via Nickel Plate & West Shore. Chicago to Montreal via Grand Trunk Railway, 837 miles.

Sailing Distances by Various Routes.

1st.	Huron-Ontario Ship Railway	1001.00 miles.
2nd.	Ottawa Navigation	978.76 "
3rd.	Lakes, Welland Canal & St. Lawrence River	1263.00 "
4th.	Mich. Pen. Ship Ry. & Welland Canal	842.25 "
5th.	Mich. Pen. Ship Ry. & Niagara Ship Ry	841.00 "
6th.	Mich. Pen. Ship Ry. & Niagara Falls Ship Canal	841.00 "

Rate of Speed (Steamers).

Rate of speed on the Ocean and Lakes, 15 miles per hour.
Rate of speed of Ship Railways and Rivers, 10 miles per hour.
Rate from Montreal to Quebec, 10 miles per hour.
Rate on the Canals, 7 miles per hour.
Rate on Welland and Niagara Falls Canals, 4 miles per hour.
Lockage and Ship Railway lifts and deflection tables, 30 minutes each.

Recapitulation—Chicago to Montreal.

		Hours.
1st.	Via Lakes, Huron-Ontario Ship Ry. and St. Lawrence River	93.14
2nd.	Via Ottawa Navigation	106.17
3rd.	Via Lakes, Welland Canal and St. Lawrence River	126.58
4th.	Mich. Pen. Ship Ry., Lakes, Welland and Niagara Falls Canal, Etc	107.04
5th.	Mich. Ship Ry. Lakes & Niagara Falls Ship Ry	90.67
6th.	Mich. Ship Ry., Lakes, Niagara Falls Ship Canal, Etc	98.39

It is necessary to give the following notes for the purpose of ascertaining the correct basis of the cost per ton per mile. On this basis the tables which follow have been prepared.

Actual Rail Rates.

From many details furnished in the paper a rate of one-half cent per ton per mile is assumed as the railroad rate over all lines. The rates over the different portions of the water route with the connecting ship railways made to cover cost of operation and 6% interest on the cost, is as follows:

Table of Cost Per Ton Mile.

Rate over Huron-Ontario Ship Ry	$3\frac{4}{10}$	mills per ton mile.
" " Niagara Falls Ship Ry	7	" " "
" on Lakes	$1\frac{1}{2}$	" " "
" " Ocean	$\frac{1}{2}$	" " "
" " Mich. Pen. Ship Ry	$3\frac{1}{2}$	" " "

Rate over Mich. Pen. Ship Canal..... 8 mills per ton mile.
" " Ottawa Route................. 5 " " "
" " St. Lawrence Canals............ 7 " " "
" " Niagara Falls Ship Canal......12.5 " " "
" " Welland Canal.................10 " " "

An important condition of the water route which should not be overlooked is the loss in time during the year on account of ice. After comparing many records showing the time of closing and opening of various routes and harbors, the table prepared by Mr. L. E. Cooley, President Western Society of Engineers, appeared to be the most reliable, and was, therefore, used in the description. The data appear under the proper head in the following table, which is the most important tabulated statement in the paper, as it contains the result of all of the calculations relating to length, time, cost and number of days of open navigation on each route.

CHICAGO TO LIVERPOOL.

No.	Description of Routes.	Length miles.	Time in hours.	Cost per ton.	No. days route is open.
1.	Huron-Ontario Ship Ry., Lakes and St. Lawrence River....	4226	13.47	$3.48	225
2.	Lakes and Ottawa Navigation..	4203.76	326.50	4.59	205
3.	Lakes, Welland Canal and St. Lawrence River............	4488	346.91	3.97	225
4.	Mich. Pen. Ship Ry., Lakes, Welland Canal, etc.... ..	4067.25	327.37	3.66	229
5.	Mich. Pen. Ship Ry., Lakes, Niag. Falls Ship Ry. & St. Lawrence.....................	4066	311.00	3.53	234
6.	Mich. Pen. Ship Ry., Lakes, Niag. Falls Ship Canal & St. Lawrence..................	4066	318.72	3.70	229
7.	All rail to Montreal..........	4062	328.33	6.26	234
8.	All rail to New York..........	4353	337.33	6.74	365

The route and plan recommended by the author is as follows: via Straits of Macinaw (or if found to be practicable and economical the route should cross the Michigan Peninsula by way of Saginaw Bay, either by ship canal or by ship railway) thence by way of Georgian Bay to Lake Ontario by the Huron-Ontario Ship Railway, the St. Lawrence canals and the river; the United States Government to build the ship railway, or ship canal, across Lake Michigan: a private company under the auspices of the Canadian Government, and by a guarantee of interest by that Government, to build and operate the Huron-Ontario Ship Railway; the Canadian Government to complete the St. Lawrence improvements to the required dimensions and then to remove all tolls from the canals. The cost of carrying a ton of freight from Chicago to Liverpool by this route as compared with the all rail route via New York will be

$3.26 per ton as against $6.74. Thus the saving in one year on the estimated traffic of 8,000,000 tons would be more than the entire estimated cost of preparing the enlarged waterway from the foot of Lake Ontwrio to the sea.

The competition in English and other importing markets of Europe between the wheat of the Northwest, the Pacific Coast, India, Russia and the Argentine is so close, that a substantial advantage in cost of transportation like the above to both Canadian and United States cereal producers will at once work a revolution in trade, and lead to an important development of agricultural products and to a material prosperity over the 450,000 square miles, comprising the basin of the Great Lakes. This prosperity will extend to the lands outside and remote from the lakes but capable of reaching its seaports, (as the great cities of the lake will be) by rail or water routes.

Ship Railways.

From a long and careful study, in his professional work, of ship railways, the author has without any hesitation placed them on an equality as transportation methods with the ship canal. In fact, he considers the ship railway in many respects superior:

1st. In that the cost of construction is generally about one-half that of the ship canal to handle the same class of vessels and an equal amount of traffic.

2nd. The cost of operation and maintenance is less.

3rd. The rate of speed is greater and the detention en route is less on account of the absence of locks.

These featnres have been discussed so fully in published papers during the last ten years in connection with the Tehuantepec and Chignecto Ship Railways that it is not considered necessary in this commercial paper to go into the detailed proofs of the statements above given.

The Mexican Government, the Dominion Government and the United States Government have each in turn officially, after long discussions and careful examinations and reports, approved of ship railways, and the leading vessel constructors, owners and navigators in England, at least, are in entire accord with the proposition. As an instance of the readiness of our own ship builders to agree to the proposition of a ship railway it may be stated that, only two or three months ago Mr. W. I. Babcock, Manager of the Chicago Ship Building Company, engaged in building large steel vessels at this city, in a written communication stated that he believed it to be entirely feasible to transport vessels of the maximum size built by his company, (namely, 400′ long, 50′ beam and of any depth) over the proposed railway between Georgian Bay and Toronto. As to the reduction in cost of transportation by ship railways it may be stated that this method is the logical result of the increasing size of railroad equipment, both motive power and freight cars. The former have increased from 30 tons to 100 tons and the latter from 10 ton cars to 30, and the transportation rates have been reduced from 2½ cents to ½ cent per ton mile.

If the immense business between the St. Lawrence and the coast of New Brunswick and New England can save 700 miles by operating a rail-

way 17 miles long across the Chignecto Isthmus, why should it continue to take this long and dangerous voyage around Nova Scotia? If engineering skill can provide lifts and a railway and motive power that can haul vessels weighing 2,000 to 2,500 tons, as already arranged for at Chignecto, who will say that it cannot design, construct and successfully operate a railway that will handle vessels weighing 5,000 tons? Necessity knows no law, and this applies to commerce as well as to other things; and the demands of this commerce and of a great people, seeking the markets of the world by the least expensive route, will be satisfied with nothing less than the most approved and economical methods which it is in the power of man to provide.

The question now arises, how can the desired and best route be provided? Will the mutual interests of two great countries between which the St. Lawrence river is the dividing line, in part, and through one of which, having passed an arbitrary line, it finds its way to the sea, bearing the commerce with it, be willing to unite to construct the ship canals and ship railways necessary to remove the obstructions to navigation? Will the great Northwest, both of the United States and Canada, with its millions of people, its rapidly growing cities, centers already of finance and commerce, with the constantly increasing business of the Great Lakes—a common heritage of both nations and free to both and God-given—will these two nations, with so much in common, permit longer arbitrary national boundary lines to remain a barrier to the commerce of both? Shall cities like Chicago, Milwaukee, Duluth, Buffalo, Cleveland and Toronto be longer compelled to send their exports to Europe and receive their imports by expensive channels, when they can load them for Liverpool or Havre at their own wharves, and receive their imports directly at those wharves from the ports of the Old World?

If the routes recommended by the author from the Great Lakes to the seaboard are enlarged and made adequate for the character ond extent of the commercial business now waiting for them, the ports and cities on the Great Lakes will then have an advantage which they can obtain in no other way. The St. Lawrence route will give to the agricultural producers and to manufacturers, to importers and merchants, and through them to the entire country tributary to the Great Lakes a direct advantage. DIRECT TRADE WITH EUROPE should be the demand of the Northwest, and of all the country tributary to the Great Lakes. There can be easily estimated a direct pecuniary advantage of not less than $200,000,000 per annum.

The proposed route lies partly in one country and partly in another. The important question to consider is, whether artificial boundary lines running athwart a natural waterway shall be permitted longer to restrict our commerce, to hamper and delay it and to divert it into unnatural and artificial channels. As civil engineers we ought to promote in all possible ways the development of this commercial route and lend our good offices to the patriotic efforts made in both countries to improve the commercial conditions of each and of what is really after all a common country.

DISCUSSION.

By Onward Bates.

Mr. Corthell is fortunate in presenting a paper of such great interest to the members of this Society as engineers and as citizens. Although the subject is treated from a commercial standpoint it is a proper one for discussion by engineers. Our profession stands at the back of the material wealth of nations, and it is within its province to propose and execute works which add to the prosperity of the people. The waterway would be enlarged under the direction of engineers, and it is they who should proclaim the practicability of doing the work, and who should make the estimate of its cost.

The proposed enlargement of the waterway involves great engineering expenditure, but this is insignificant in comparison with the commercial benefits which would ensue. The improvement of the St. Lawrence canals and the construction of the Huron-Ontario Ship Railway will make a seaport of every harbor on Lakes Huron, Michigan and Superior. An examination of the maps of our country will show systems of railways radiating from each of these ports, and covering with the network of their tracks. what is perhaps the richest in natural resources of any section of the earth. The capacity of this section to supply the needs of the world is only limited by ability to distribute its products to the needy. The lakes and the St. Lawrence river constitute the gateway to this great producing section, but there are closed gates at the St. Clair, Detroit and Niagara rivers, and the St. Lawrence rapids. A canal or ship railway from Georgian Bay to Lake Ontario, and the enlargement of the St. Lawrence canals will open new gates through which will pass a volume of traffic going and coming between this country and those skirting the Atlantic ocean, of such an extent as to make estimates of its magnitude appear too great for belief. In Mr. Corthell's paper he has cleverly prepared our minds to receive such estimates, by his statement of the development of our rail and lake commerce to its present proportions, and without this knowledge we should be unable to conceive what may be the result of such a waterway for the largest class of vessels.

Mr. Corthell has collected and embodied in his paper a great amount of valuable data bearing on the subject. The scope of his paper has not permitted a description of the engineering features of the proposed works. The data is not given from which to check his estimates of cost. These are largely compiled from existing records and he has stated his authorities for them. His figures are doubtless sufficiently accurate for a comparison of routes and schemes, and the amounts of the estimates are so small by the side of the great results which may be expected, that a liberal margin for variation may be assumed without affecting the conclusions which his paper leads to. These estimates can be checked by surveys and detailed plans, and it is probable that contractors can be found who will name a sum for which they will agree to execute the works.

To the writer the route across the Ontario peninsula stands first and alone. This may be considered independently of any of the other schemes proposed in connection with the improvements of the upper St. Lawrence. Its only competitor is the Ottawa Ship Canal from Georgian Bay to Montreal, which may be removed from consideration on account of its great cost. The Huron-Ontario route gives more direct service to ports on Lakes Huron, Michigan and Superior than any Lake Erie route; besides being stated as cheaper in cost and operation. It however does not serve Lake Erie ports, but in the writer's opinion the advantages of the short route should not be sacrificed upon this account. The Lake Erie route should be treated separately, and in the event of the Huron-Ontario one proving successful, the necessary enlargements of waterway between Lake Erie and Lakes Huron and Ontario would follow as a natural sequence. The same reasoning applies to the Michigan Peninsula Ship Canal or Railway, which should stand on its own merits and be considered apart. The Huron-Ontario and St. Lawrence route is a complete one in itself and when executed, if developments required the other schemes they would follow by the law of progress and ultimately form portions of a complete system of waterways.

Assuming the Huron-Ontario route to be adopted the question is open whether it shall be a ship canal or a ship railway. From Col. R. B. Mason's examination of the route in 1855 and his estimated cost of $22,170,150 for a canal with locks 12 feet deep, it may be assumed that the cost of a canal for vessels with a draught of 20 feet will be so great as to put it out of the question when compared with the cost of a ship railway, which Mr. Corthell estimates at in round numbers $15,500,000. Concerning the cost and efficiency of ship railways, they have been thoroughly discussed, and have been approved by engineers of the highest professional standing both in this country and abroad. Further theoretical discussion of them is not required at this time. The writer has believed in them since Capt. Eads' presentation of their merits for his proposed Tehauntepec Ship Railway. The time is ripe to test them by experience, and if the profile of the Huron-Ontario route is as suitable as stated in the paper under discussion a more favorable location for such a railway could not be found.

That in the paper which has most impressed the writer are the small sums for which the enlarged waterway may be secured. The Huron-Ontario Ship Railway is estimated to cost $15,500,000, and the enlargement of the St. Lawrence canals $27,000,000, or a total for both of $42,500,000. About the cost of a small sized granger railroad. These are days of great enterprises, and the investments of aggregations of capital, and with the known economy of deep water transportation, it would appear to the writer that such an enterprise offers greater and safer inducement for the investment of capital than does any new railroad construction at this period.

Mr. Corthell treats the project for an enlarged waterway as an international one, and it is such in so far as the commerce to be carried on it is concerned, but both the Huron-Ontario Ship Railway and the St. Lawrence canals will lie in the Dominion of Canada. As the paper is of an

international and commercial character, the writer may be excused for stating that in his opinion it presents a strong argument in favor of free trade. If we can't have free trade then the next best thing is annexation, and perhaps Canada will be willing to build the ship railway in exchange for the privilege of annexation. An enlarged waterway through which foreign gunboats could steam up to Duluth would raise a question of national moment which would be forever settled by Canada joining the sisterhood of states. Such a waterway should be a blessing to both countries, and the direct and indirect advantages which would accrue to the citizens of each, invite the cordial co-operation of their respective governments. It should form a bond of union between the two greatest of nations, and a step toward that time when all nations shall be at peace.

By St. John V. Day.

By the courtesy of the author I have been favored with a copy abstract of his paper read before the Canadian Society of Civil Engineers in February last.

I have, as requested, studied the abstract closely and with a deep interest in the engineering projects the paper deals with. It seems to me unnecessary to discuss the question, whether enlarged facilities for accommodating so rapidly an increasing commerce between the East and West of this great continent should be further considered—for the figures with which Mr. Corthell's paper bristles unquestionably prove that to be a foregone conclusion, and in respect to which no further discussion is therefore necessary.

Not only does the international development of the trade and commerce of America and Canada, nay, that of the whole North of the Western Continent, demand such increased and capable facilities for the transport of shipping—but not one whit less is Europe, and England especially, interested in such increased facilities. Why should European freight carriers on their outward voyages be longer compelled to discharge their cargoes at the eastern ports of the United States and Canada only, when the second city of the United States—Chicago—situate far in the interior, has become the heart of the northern half of this great continent—the city towards which all the great lines of railway have made—thus acknowledging it to be the natural focus of what must erewhile become the greatest commercial city of the Union—the commercial capital of the Union! Unquestionably Chicago must benefit largely, must inevitably have its present prosperity and development added to by increased facilities for bringing to its harbors the freight carriers of the great ocean. Whilst putting facts relating to Chicago alone in the front place, which is their natural position, it is not in the least to disparage the improvement which such increased shipping facilities would bring to the other great cities around the lakes; but the pre-eminence of Chicago in itself, when considered alone, is more than enough to prove the necessity of such a work as Mr. Corthell proposes. We have only to bear in mind that out of a

total of some 170,000 miles of railway in the United States and Canada, not less than 54,411 miles terminate in this city, and that not less than about fifty millions tons of freight were received and forwarded here last year.

This matter has also another side, for it is of great importance also to Europe, whose shipping interests must benefit largely by not having to unload at an eastern port, freight destined for the interior and west without having to "break bulk" through unshipping and re-shipping. The construction of such a work as would constitute adequate shipping facilities between the St. Lawrence and the Great Lakes is not in any sense a mere national question in which one, or at most two countries are concerned—it is of equal importance to every country which does a shipping trade with the northern half of the Western Continent—for with the rapidly increasing population of the West, and the incessant and continued march forward of civilization thitherward, other countries, in order to reap the benefits due to the fair distribution of their products at the lowest prices, are not less concerned in such an undertaking.

Mr. Corthell has I think convincingly shown that the whole journey of sail between Chicago and Liverpool may be performed by a system of communication between the Atlantic and the Great Lakes which does not present by any means what may be considered as engineering difficulties, but which as engineers, we can, with the fullest confidence pronounce to be of certain possibility of construction, no less than of certain commercial success. The growth of population, the expansion of industry in the Western States, demands the easiest means of intercourse with the rest of the producing and consuming nations.

Mr. Corthell has shown that by the proposed Huron-Ontario Ship Railway the cost of conveying a ton from Chicago to Liverpool would be $3.48, whilst the cost for conveying a ton by rail to Montreal or New York and thence by ship to Liverpool, amounts to $6.22 and $6.74 respectively—so that by this proposed ship railway connection between the lakes and the Atlantic seaboard the cost of conveyance would be little over one-half; whilst in respect of time there would be a gain of a little over a half day as compared to the Montreal rail route, and almost exactly one entire day in the case of the New York rail route.

In respect to all the other routes, viz: the Lakes and Ottawa Connection; the Lakes, Welland Canal and St. Lawrence River; the Michigan Peninsular Ship Canal and Ship Railway; the Michigan Ship Railway, Lakes and Niagara Falls Ship Railway and the Michigan Ship Railway, Lakes, Niagara Falls Ship Canal, etc., Mr. Corthell has shown that the proposed Huron-Ontario Ship Railway, Lakes and St. Lawrence River has, with one exception, a clear gain all round of time and cost.

The points I have thus far dealt with compass I think the main commercial considerations involved in this matter, and I now proceed to deal with some of those points which more especially apply to the province of the civil engineer.

Whether a great canal or a ship railway be the more proper method or means of communication between the lakes and the Atlantic depends

very largely for its solution upon the future work of the naval constructor, the ship builder.

In following the development of naval architecture as I have been privileged to do, through much professional occupation at the ports and rivers of the United Kingdom and elsewhere on the European continent—more especially on the Mersey, at Barrow, the Tyne, the Wear, the Clyde, at Belfast and elsewhere, nothing so much strikes an engineer who may he concerned in designing or constructing docks, canals, wharves or other works for the accommodation of shipping—as the growth in certain dimensions of the ships which have been built during the past decade.

I regret that I have not my note books with me which contain a record of this growth, which has taken place principally in two directions, viz: in length and breadth of beam; there has not been a marked increase in the immersion depth, for the reason that most of the harbors or docks cannot float a ship of over twenty-one feet of immersion depth.

The experience of the past twenty years in this respeet certainly tempts us to assert that in this age, pre-eminently the age of big things, there are certainly no facts in existence which will enable anyone to predict what will be the size of steamships ten years hence. Most emphatically it may be said that in no respect, save in regard to depth of immersion, which of course is fixed by the depth of water over the sills of the great docks of the world, does a limit to size appear for naval architecture, as in all other structural work, a limit is no sooner set than someone finds a way of overleaping it, and then the limit is advanced further off.

I have been led to these remarks from the fact of their having such an important bearing upon the dimensions and character of the works which must sooner or later be constructed to connect the Great Lakes with the Atlantic seaboard, to provide for the passage of the heaviest freight carriers, quite irrespective of whether these works consist of a canal or of a railway.

If a canal be constructed it would not, in view of the progressive advance in the dimensions of ships, be wise to make the locks less than twice the length of the largest cargo-carrying ships now afloat and not less than twice their present breadth; whilst in regard to the depth and breadth of the canal, the total canal prism should not be less than double that necessary to accommodate the existing freight carriers.

These considerations show that the cost of canal works adapted to the present growth in dimensions of shipping would by virtue of that adaptation be run up to a high figure; but on the whole this would ultimately be of much less expense than to successively enlarge the locks and the prismatic section of the canal, such as would be necessary to accommodate the future growth in the dimensions of ships.

In the case of the railway as a means of transporting ocean freight carriers to the lakes and vice versa, whilst it is true, as Mr. Corthell has pointed out, that we have as yet no experience of transportation of ships by this method—yet, with the practical experience which engineers have had in lifting ships out of the water by traction on the rails of slip docks coupled with the further knowledge possessed in respect of the insistent

load upon driving wheels on rails necessary to overcome the tractive resistance at any given speed of any required amount of dead load such as we might consider a ship with its cargo to be when placed in a cradle or truck on wheels, and this again on railroad tracks—it is certain that a railway adapted for such heavy transportation may be much more easily and more quickly constructed, and that at a much less cost, than a canal of such dimensions as I deem necessary.

A railway too, if made at first of sufficient width, could without very much increase of first cost, be built capable for the transmission of shipping which will, almost to a certainty, be characterized by growth in length and breadth of freight carrying vessels for many decades to come; and this I deem one very decidedly attractive feature of the ship railway as compared to a ship canal; therefore I can arrive at no other conclusion than that Mr. Corthell is in every way right in recommending a great ship railway as the best system for connecting the water terminals of the navigation of the Great Lakes and the Atlantic. It should, as I conceive such a road, have a complete "up" and "down" track for the entire distance, for sidings and switching in such a case present several difficulties.

The abstract of the paper does not indicate whether Mr. Corthell has worked out the dimensions of the railway he proposes, beyond stating that three tracks will be used—I presume he means three tracks side by side—the rails of these tracks to weigh 110 pounds per yard. Nor does Mr. Corthell indicate the construction of the cradle or truck and its railways for receiving and carrying ships when in transit upon said railway—nor the system of haulage or locomotive power to be used. Judging from the experience we have in raising ships on slip docks, I conceive Mr. Corthell's time estimate for getting a ship out of the water and on to the railway much too short.

It would be of much benefit if Mr. Corthell would supplement his present valuable paper by such details of the ship railway as I have indicated.

In the case of locomotives being used, I would suggest that they need not be extremely heavy in themselves as by a system I have some time ago devised for diminishing the dead weight of locomotive engines without loss of adhesion of the driving wheels, part of the dead weight of the ship itself can be utilized for producing the adhesion necessary for overcoming the tractive resistance of the load.

I need only remark in conclusion that I am sure engineers generally will feel grateful to Mr. Corthell for his valuable paper; whilst to myself individually it is a pleasure to add that I feel conscientiously compelled to indorse his views in regard to the proposed ship railway.

By Chas. D. Marx.

It seems a pity that Mr. Corthell has presented but an abstract of his valuable paper before our Society for discussion. A review of it under such conditions is likely to work injustice either to the reviewed or the re-

viewer. Mr. Corthell presents in a condensed form, estimates of cost of construction and operation, length of line and of season of navigation, for the various routes considered. He compels us thereby either to accept his figures as correct, that is accept his values of the factors which largely go to determine the choice of a line, or to carry out for ourselves in a few short days, a verification of data, which it must have taken him months of earnest and conscientious work, yes on some points, even years of such, to collate, sift and arrange. Then too, I am aware that Mr. Corthell has had access for forming his opinions and estimates to material, which is not readily accessible to his reviewers. For one I am willing under the circumstances to accept Mr. Corthell's estimates as correct, and still to differ somewhat from him in the conclusion as to the most desirable route. So let us glance briefly at some of the routes on the Canadian side.

The Trent Valley project is condemned for good and sufficient reasons. Though the government still holds forth in the blue book, I think, the promise of an inland waterway connection between Lakes Ontario and Huron, by way of the lakes of the New Castle district of Upper Canada, that line would be entirely unfit for a waterway of the commercial importance outlined. In the summer of '87 I had occasion to make a pretty thorough study of the possibilities of the Trent Valley Canal. Prof. Galbraith of the Toronto School of Science and myself made careful determinations of the low water inflow into Balsam Lake, the summit level of this route, and unless exceptional storage capacity is provided difficulty will exist in obtaining a sufficient supply of water for a canal with only five feet of water on the sills of the locks. With a fall of 118.5 feet between Balsam Lake and the mouth of the Talbot River, a distance of about 13¾ miles of canal, without any intermediate feeders, it becomes at once apparent that for a brisk navigation, a large supply of water would be needed to make good the losses by leakage, evaporation and percolation. The canal would have to be cut through limestone, similar in character I believe to that in which those sections of the Erie Canal are cut, on which Mr. Searles determined in 1877, the losses by leakage, etc., to be about 345 cubic feet per mile per minute. Length and lack of water are sufficient reasons to condemn this line.

There remain then for our consideration the Ottawa Ship Canal project and the proposed Georgian Bay and Toronto Ship Canal or its alternative the Huron-Ontario Ship Railway. The first of these routes, assuming Mr. Corthell's figures, calls for an outlay of $83,000,000, a sum which would almost seem prohibitory, but we must look at this outlay a moment from the Canadian standpoint. The construction of a canal along this line will open up a large tributary territory in Ontario and Quebec. Lake Nipissing furnishes an ample supply of water on the summit level, and thus removes one of the obstacles in the way of successful canal operation. I presume Mr. Corthell's estimate is based on the assumption of heavy rock cuts in the granite which will be all along this line. A resulting advantage will be decrease of loss by infiltration and percolation.

The Toronto Ship Canal project was condemned by a Canadian Commission not later than 1871 on account of its impracticability and great

cost. In its place Mr. Corthell proposes to substitute a ship railway. He claims cheapness of construction, ease of operation and shortening of line or his scheme. Granting all these there still remains the question, whether it would not be an easier matter to raise in Canada with government help $83,000,000 for the building of an internal improvement like the Ottawa Canal, than it would be to raise in and outside of Canada $16,000,000 for building Mr. Corthell's ship railway. It is possible that in case the Canadian government guarantees the interest on the sum mentioned by Mr. Corthell, home and foreign capital will not be lacking for carrying out the work. But will the government be likely to take a step of this kind? May it not be a wiser move for the administration, especially as matters stand at present, to inaugurate a vigorous policy of developing *Canada through Canada* rather than the *United States through Canada?*

I agree fully with Mr. Corthell as to the desirability of that happy condition when artificial boundary lines or obstructions will no longer add to the natural ones, which often enough and sorely too, perplex the engineer in the solution of his problems. But with all that we must bear in mind that in our profession we are most often called upon to deal with facts, the stubbornest of all things. One of these important *facts* in Mr. Corthell's problem, is the very one on which he touches but lightly at the end of his paper, and has become the one to lead me to differ in my conclusions from his. As civil engineers we undoubtedly ought to lend our good offices to the patriotic efforts made in both countries to improve the condition of each and of what is after all the common country; but as civil engineers we must also not lose sight of the *fact*, that a universal peace era has not yet dawned upon us. Reciprocity may and may not mean an ultimate federation of Canada with the United States. Until we have more light on that subject, I for one would prefer to see the adoption of route five or six, as outlined by Mr. Corthell.

Of the necessity and feasibility of an enlarged waterway between the Great Lakes and the Atlantic seaboard, Mr. Corthell must have succeeded in convincing all who may have had any doubts on the matter. Those of us too, who have been in sympathy with him right along owe him a debt of gratitude for his admirable presentation of what many may have thought, but few could have put so well.

By Benezette Williams.

In complying with Mr. Corthell's request that I discuss his paper, "An Enlarged Waterway between the Great Lakes and the Atlantic Seaboard," I wish to disown any intention of entering into the merits of the various routes proposed, from an engineering point of view. This could only be done intelligently after an exhaustive study of the detail surveys and other matters pertaining to such routes, which lack of time and lack of data have not permitted. The most that I can hope to do is to make a few suggestions which readily occur to one not well informed on either the engineering or commercial phases of the question. In all matters involving

engineering problems I shall rely upon our author, than in whom none can place reliance more safely.

The paper having been prepared for the Canadian Society of Civil Engineers, the author is doubtless excusable if it should develop in the course of the discussion that he lost himself for a time, and temporarily appeared in the role of a loyal Canadian, upon whom the doctrines of reciprocity have not had their perfect work. With the patriotic influences from this side of the lakes, surrounding him to-night, we may reasonably hope to see him recover his equilibrium, and view the great problem which he has so at heart, from the standpoint of a statesman who would break down all commercial barriers and consult the interests of all the cities upon the great chain of lakes without reference to the allegiance which they acknowledge.

The selection of the Georgian Bay and Toronto route to Lake Ontario would leave the cities on Lake Erie and the Detroit river dependent upon the Welland Canal, with its narrow locks and 14 feet of water, for access to the ocean. Buffalo, Cleveland, Toledo and Detroit with an aggregate population of 804,324, with their immense commercial and transportation interests, to say nothing of cities of less importance, cannot be ignored when it comes to settling upon a deep water route to the seaboard.

The sailing distance from Chicago to Montreal via the lakes, Niagara Falls and St. Lawrence river, as given by the author is 1,263 miles. A ship railway from Georgian Bay to Toronto on Lake Ontario will shorten this distance 262 miles, and reduce the time from 109.74 hours to 93.14 hours, a total reduction in time of 16.60 hours. On the other hand the cost of the Georgian Bay and Ontario Ship Railway is given at $15,459,318.09 while the cost of a ship railway around Niagara Falls is given at $10,731,613.71, a saving of $4,727,704.38 in favor of the Falls route.

The cost of transportation per ton via the Niagara Falls Ship Railway as nearly as I can make out on the basis given by the author will be 44 cents more than via the Georgian Bay Ship Railway, making the total cost per ton to Liverpool $3.92 instead of $3.48.

The correctness of this comparison, however, is dependent upon the cost per ton mile assumed by the author for the various portions of the route.

Without undertaking to enter, in much detail, into the cost of transportation by various means, it would be interesting to hear what the author has to say with reference to a few points which render it difficult for me to accept the basis of cost given by him in its entirety.

He gives a table of rates per ton mile for various parts of the route, and various means of transportation, and another one of the total cost per ton, and the time, between Chicago and Liverpool. The time and cost in the latter table, as I understand it, is for craft which will pass through channels having 20 feet minimum depth of water, loaded in Chicago and making the trip to Liverpool without breaking bulk, and with the same crew all the way from Chicago to Liverpool.

This being the case it is hard to understand why the cost per ton mile

should be 1½ mills on the lakes and only ½ mill on the ocean, particularly as the speed given for the lakes and ocean is the same—15 miles per hour.

Also, while assuming the St. Lawrence Ship Canals to be free, in the completed scheme, he takes the rate for passage through them as if they are to pay an interest on their cost in tolls, and inadvertently uses this in determining the total cost of carrying freight to Liverpool. This of course does not affect the comparative cost by the different routes that use the St. Lawrence but it does those that do not.

In this table of rates there is a rather curious anomaly noticeable in the comparative cost of carrying freight over the same routes by ship railways and by canals.

For instance the rate over the Michigan Peninsula Ship Railway is 3½ mills, and over the Huron-Ontario Ship Railway 3.4 mills per ton mile; while over the Michigan Peninsula Ship Canal it is 8 mills per ton mile. Over the Niagara Falls Ship Railway it is 7 mills, while over the Niagara Falls Ship Canal it is 12½ mills per ton mile. The length of the former is 18½ miles while the length of the latter is 25 miles. Taking the length into consideration the cost of transporting a ton of merchandise from Lake Erie to Lake Huron around the Falls over the two proposed routes would be by ship railway 13 cents, and by ship canal 31 cents; a marked difference which to one unacquainted with the proposed method of operating ship railways seems almost incredible.

The freight rate as given by the author from Chicago to the seaboard over different lines of railroads, is 5 mills per ton mile, which when compared with the cost given for transportation by ship canals, shows that transportation over ship canals 20 feet deep, costs from 40 to 150 per cent. more than by existing lines of railroads.

I believe it is an established fact that the rate per ton mile on the New York Central & Hudson River Railway, from Buffalo to New York City, is as low as upon any road in the United States. Running almost parallel with this road, throughout the whole distance to the Hudson river, is the New York and Erie Canal, with 656½ feet of lockage, and but 7 feet depth of water. But notwithstanding the inadequacy of the size of this canal, and the very small boats which can navigate it as compared with those adapted to navigate a 20-foot channel—a ratio at least as great as 1 to 10—it carries 5,000,000 tons of freight between Buffalo and New York every year at a cost not exceeding 3 mills per ton mile.

I know that the answer to this is that the railroads pay an interest on their cost and operating expenses while canals are generally free. To this we may reply that railroads have been improved and double-tracked, sometimes twice over, and their rolling stock has been improved to that extent that in the State of New York the rate for freight per ton mile has decreased from 2.79 cents in 1855 to one-half cent in 1890.

It should be remembered that railroads have been in the hands of active and aggressive men, servants of the great corporations, while the canals have generally been in the hands of State legislators who have to a

large extent been also servants of the same corporations. The difference is immense.

Still another anomaly confronts us in the author's table of rates, in that the cost per ton mile by ordinary rail transportation is 5 mills, while that by the proposed ship railways is 3.4 and 3.5 mills, a difference of 30 per cent. in favor of the ship railway. This would tend to show that railways are operated on a wrong system, and that economy in rail transportation lies in hauling ships instead of cars across the country.

While by the foregoing comparison of rates, I am led to believe that Mr. Corthell has unconsciously fallen into an undetected fallacy in the cost of carrying freight by ship railways and ship canals, we will for the present waive this point, and merely correct his table of rates so far as it relates to lake and river carriage. As before pointed out, there is no reason, on a through trip with ships of heavy tonnage, why the rate per ton mile on the lakes should be greater than on the ocean. In the following tables I have taken the lake rate at ½ mill—the same as for the ocean—and the river rate at ¾ mill. Aside from the inconsistency of using a different rate on the lakes from that used on the ocean, actual experience shows that ½ mill per ton mile is sufficient for through traffic. Freight is being carried between Chicago and Buffalo, including terminal delays, for about ⅔ mill per ton mile. Allowing for the terminal delays, ½ mill is found to be ample for through lake traffic. For rivers I use ¾ mill as being the proper rate, based upon the relative speed given by the author, on river and lakes, viz., 10 miles and 15 miles per hour respectively.

I.

CHICAGO TO MONTREAL VIA LAKES AND NIAGARA FALLS SHIP RAILWAY ROUTE. TIME: 109.74 HOURS.

Kind of Navigation.	Distance. Miles.	Rate per ton mile. Mills.	Total Cost.
Lakes	971½	½	$ 0.486
St. Clair River	41	¾	0.038
Detroit River	27	¾	0.023
Niagara Falls Ship Railway	18½	7	0.130
St. Lawrence Canals	43½	7	0.305
St. Lawrence River	161½	¾	0.121
Total to Montreal	1263		1.103
Montreal to Liverpool. St. Lawrence River and Ocean	3225	½	1.612
Total Chicago to Liverpool	4488		2.715

II.

CHICAGO TO MONTREAL VIA GEORGIAN BAY AND TORONTO ROUTE.

TIME: 93.14 HOURS.

Kind of Navigation.	Distance. Miles.	Rate per ton mile. Mills.	Total Cost.
Lakes	730	½	$ 0.365
Huron-Ontario Ship Railway	66	3.4	0.225
St. Lawrence Canals	43½	7	0.305
St. Lawrence River	161½	¾	0.121
Total to Montreal	1001		1.016
Montreal to Liverpool. St. Lawrence River and Ocean	3225	½	
Total Chicago to Liverpool	4226		2.628

III.

CHICAGO TO MONTREAL VIA MICHIGAN PENINSULA SHIP RAILWAY AND NIAGARA FALLS ROUTE. TIME: 90.67 HOURS.

Kind of Navigation.	Distance. Miles.	Rate per ton mile. Mills.	Total Cost.
Lakes	459.	½	$ 0.230
Michigan Penin. Ship Railway	158.5	3½	0.555
Niagara Falls Ship Railway	18.5	7	0.130
St. Lawrence Canals	43.3	7	0.305
St. Lawrence River	161.5	¾	0.121
Total to Montreal	841		1.341
Montreal to Liverpool. St. Lawrence River and Ocean	3225	½	1.612
Total, Chicago to Liverpool.	4066		2.953

The tables show the cost of carrying freight per ton from Chicago to Montreal and thence to Liverpool, without breaking bulk, on the revised basis as given above, over three of the routes given by Mr. Corthell, viz.:

1. Via Lakes, Niagara Falls ship railway and St. Lawrence river and canals.

2. Via Lakes, Huron-Ontario or Georgian Bay ship railway, St. Lawrence river, and canals.

3. Via Lakes, Mich. Peninsula ship railway, Niagara Falls ship railway, St. Lawrence river, and canals.

The above tables show that granting all that the author claims as to the efficiency and cheapness of ship railways as freight carriers, that the route via the Huron-Ontario ship railway has but nine cents per ton advantage over the lakes and Niagara Falls route; and that the Michigan Peninsula ship railway line is at 24 cents per ton disadvantage compared with the same route.

In view of these facts, and of what seems to me the political and commercial necessity that a deep water route to the seaboard should follow the line of the large commercial cities, and should be such as to serve every one alike; and that by the author's estimates the first cost of the route via Niagara Falls is $4,727,704.38 less than via Georgian Bay and Toronto, it seem sthat the latter route should be finally eliminated from the problem. The same way be said. still more certainly, of the proposed Michigan Peninsula ship railway or ship canal.

This conclusion is made still more emphatic by the fact that by far the greater tonnage which will be carried on such a route is local and not transatlantic; being traffic between upper and lower lake ports. The few hours difference in time which is shown to exist—viz. 16.6 hours—is insignificant when compared to the great commercial and political advantages in following the chain of lakes and rivers which nature has marked out. In such a case a few hours more or less is immaterial except as it may affect the through cost of transportation. This, as shown by the author, amounts to 44 cents per ton between Chicago and Montreal. But by taking the author's real basis, corrected in its application, as heretofore shown, the difference of cost is but 9 cents per ton. A slight increase in the cost of carriage by ship railways will show that the Niagara Falls route is materially cheaper. That such an increase should be made, I believe, will become apparent on further consideration of the problem of moving vessels in the manner proposed.

In the discussion thus far I have assumed that Mr. Corthell's conclusions concerning the feasibility of ship railways, are in the main, correct, and that there are cases where they may become a valuable adjunct to water transportation. But in the course of his arguments to establish their value as the carrier of ship and freight, as compared with canals, there must lurk a subtle fallacy, or else past experience in the operation of railroads and canals is misleading. One of the fallacies which the author falls into may perhaps consist in the assumption that it will take no more time for a ship to be placed on the gridiron, or cradle, adjusted properly and hauled out of the water, ready for movement over the main track, than it takes to pass through a single lock on a properly constructed canal. Another one may be in assuming that the movement over the railway will be more expeditious than through a canal. If, in accordance with the author's assumption, 8,000,000 tons of freight will pass over the route during a season of navigation, there will, in all probability, be days when

one vessel an hour and perhaps more would pass over the track. This will necessitate frequent sidings and consequently serious delays because of them; or it will render a double railway necessary. With a ship canal of proper width there would be one continuous siding so that meeting vessels can pass freely at any point. Hence, it does not seem probable that the movement of vessels over a ship railway can be made more expeditiously than through a canal. It should be borne in mind that on such a route there will be not only the large ships of 2,000 to 3,000 tons burden, but there will be a multitude of small craft, each of which must be handled separately.

The difficulty, and as seems probable, the impossibility, of handling 8,000,000 tons of freight in a heterogeneous lot of craft, such as navigate the lakes, in a season, over one line of road is, I believe, demonstrated by the Sault St. Marie canal. At this canal upwards of 9,000,000 tons was passed last year. The lock for the same is 515 feet long, 80 feet wide, with 17 feet of water on the miter sill. In passing vessels it is usual to let in several at a time, and even then, as I am informed, great delays occur not infrequently, and it is at times being taxed to its full capacity. To meet the growing needs of commerce, as shown by the author, a new lock 800 feet long, 100 feet wide and 21 feet of water on the sill is being constructed. From such information as I can get on the subject, one line of ship railway could not possibly have handled the traffic of the Sault St. Marie canal, presented as it is irregularly and spasmodically. Then it should not be forgotten that if ample facilities were furnished, the tonnage to pass over such a route as that to the seaboard, is likely to grow far beyond the limit of 8,000,000 tons per year.

From the various considerations I am forced to the conclusion that it would be useless to start on a ship railway enterprise on any portion of such a route with less than a double track all the way through. This would have the effect of increasing the capital account from the first by almost 100 per cent., certainly by as much as 75 per cent., which alone would increase the rate per ton mile materially, and even then I believe it can be shown that such a railway would have less capacity than a ship canal.

There are still other reasons for thinking that the cost of shipment via ship railways should be greater than given by the author, and that the comparison with canals as shown in his table of rates is at fault.

It has been found that the operating expenses of railroads amounts to about 66 per cent. of their total income, that is, two-thirds of the money collected for carrying freight and passengers on railroads goes for operation, and one-third to pay interest on invested capital. If it be granted that it will take a relatively smaller proportion of the total earnings to operate a ship railway, it is still probably not out of place to assume that the cost of operation capitalized, will, when the traffic is heavy, nearly, if not quite equal the first investment. There is, of course, a possibility that there are cases, even when plenty of water is to be had to feed a ship canal, that a ship railway will prove the cheaper, including first cost

and cost of operation, and such a case may be the passage from Lake Erie to Lake Ontario around Niagara Falls.

There is another matter of interest suggested by Mr. Corthell's paper, about which I have made some endeavor to obtain information, but without success, and that is, the carrying capacity of ships which can be built, adapted to navigate the lakes, canals 20 feet in depth, and the ocean, plying between Chicago and Liverpool, and other freight ports. Can such vessels be made of sufficiently great capacity to compete on the high seas with ships engaged exclusively in the ocean carrying trade? To do this it is to be presumed that such ships will have to be of, at least, an equal capacity to those nondescripts known as ocean tramps.

These questions open up a phase of the subject which should have thorough consideration before such an enterprise as that proposed is undertaken, and a depth should be fixed upon, which will place lake ports on a par with those on the seaboard, so far as the handling of freight is concerned, barring their extra distance from foreign ports.

The figures showing the immense and rapid increase of commerce on the lakes, given by Mr. Corthell, are sufficient to convince the most skeptical. of the folly of undertaking such an enterprise on any other than the broadest lines. In such an undertaking depth should be sought rather than directness of course, and the ability to touch all important points rather than the mere shortening of time by a few hours. The service to which such a waterway would be put, is that of carrying freight, rather than passengers. Do what you will, passenger travel will always follow the line which can be traversed in the shortest time without regard to cost. What is needed is that channel which will carry the grosser kinds of freight the cheapest without regard to a difference of a day or two in time.

To me it seems clear that we do not need to go beyond the data furnished by Mr. Corthell, with so much work and painstaking, to establish the route via the lakes, Niagara Falls, and the St. Lawrence river as the proper one for an enlarged waterway to the seaboard. On this route a twenty foot depth already obtains to the Falls, and a twenty-four foot depth can doubtless be obtained at a cost which will be moderate as compared to its importance. As to whether a ship railway or a ship canal should be built around the Falls is a matter which can only be settled after a careful preparation of plans and estimates, and after the object lesson which is being given at Chignecto shall have been completed and better learned. As to the feasibility and expense of improving the St. Lawrence to a twenty or twenty-five feet depth, let those speak who have more material to work from than have I. This much, however, is clear to me that if it were necessary to spend from one hundred to two hundred millions of dollars to get a wide channel twenty-five feet in depth from Chicago and Duluth to the seaboard, that no better outlay of this amount of money, from a commercial point of view, can be made. If Mr. Corthell's paper is the instigating cause of a movement, which ultimately culminates in such a fruition, the whole country will owe him a debt of gratitude which money cannot pay.

THE OUTLOOK FOR LOCAL AND GENERAL ENGINEERING SOCIETIES.

Annual Address of William H. Searles, President, Civil Engineers' Club of Cleveland.

[Read March 10, 1891.]

The swiftly circling year has brought us once again to this anniversary occasion, and while we meet to exercise our constitutional rights as members of the club in the selection of officers, our minds involuntarily revert to the past and call up similar scenes in which we have participated. Although our club has not yet many years to boast of, yet its record has certainly been gratifying, even to its most ardent well-wishers. The lines on which the club was founded have been faithfully adhered to, and while a progressive spirit has marked its career, this has been tempered by a commendable conservatism. The professional work of the club has been cheerfully performed, and compares favorably with that of similar institutions both in quality and quantity. In proportion to membership this club has probably not been exceeded by any other society of engineers in the number of valuable papers read since its organization eleven years ago. The discussions following these papers have been most interesting and useful to the members in comparing individual views and eliciting unexpected information on various scientific and practical subjects. The dignity and decorum which have attended your proceedings rival those of the most august assemblies, showing at once a respect for the club as an institution, a deep interest in its work and a most kindly sentiment of fraternity on the part of the members, one to another.

Nor has the social side of the club been neglected, as will be attested by all who have attended our various gatherings from time to time. These occasions have usually been so successful in promoting social enjoyment, in cementing the bonds of friendship among members, and in strengthening the sinews of the club for further work, that it is to be hoped facilities may be provided for their more frequent occurrence. There is a true philosophy in employing the art of dining to subserve some grand purpose,—to make this art the graceful and efficient handmaiden of the sister arts of nobler degree. This is becoming much better understood than formerly,—the festive board is now the almost unfailing concomitant of every great enterprise, a marked feature in the expression of every important association. And so, in our own case, the annual banquet has passed from the uncertain stage of doubtful policy, to be now regarded as an established fact, a factor of unmitigated good to the greatest number—a beneficent feature of our organization.

But the full efficiency of the social feature in promoting scientific

ends will not be realized until these annual gatherings of the membership shall be supplemented by monthly reunions, similar, but on a smaller scale, less formal, but more social, held, not in a public hall, but in the rooms of the club, enlivened, not by the addresses of appointed speakers, but filled with the hum of many voices to the accompaniment of chiming spoons and tinkling glasses.

To accomplish this most desirable end a *home* for the club becomes a prime necessity. For a year this matter has been under discussion. Is it not now time to act? There are several considerations which make this step advisable at the present time, and I will limit my remarks to a brief mention of them.

In the first place it is not likely that the club will be able to continue long in its present quarters, owing to contemplated alterations of the building, the enlargement of Case Library and other contingencies.

Secondly. The present room while well adapted to the Club in its infancy is quite inadequate to present needs, even if it could be retained. It affords no opportunity for anything more than an audience room for the reading of papers at the monthly meeting and even for this purpose it is sometimes painfully inadequate.

Thirdly. The objects of the Club as constitutionally defined can only be carried out in quarters over which the Club has full control by lease or purchase, from which the general public shall be excluded, but where every facility shall be extended to members for private study, reference to the library, and mutual consultation on professional questions, and last, not least, opportunity for those frequent social reunions to which allusion has already been made.

Fourthly. The trend of events during the past year makes it of the first importance that the Civil Engineers' Club of Cleveland should take a more prominent position in the engineering community of the country than ever before. Various schemes have been promulgated during the past two years for affiliating the several engineering societies. Chiefly an effort has been made by which the American Society of Civil Engineers of New York might bring into affiliation with itself the other societies of the land, or failing in this, might organize local chapters out of its widely scattered membership, which chapters would be in direct, though not unfriendly competition with existing local societies. But this movement has resulted in nothing,—a proposed amendment to the constitution of the American Society providing for chapters or branches, has met with signal defeat. The principle is established that each of the engineering societies is, and of right ought to be free and independent of every other, while maintaining the most friendly attitude toward one another. While each society is localized as to its headquarters it is free to select its members from the entire country or the world. Thus our own Club in a measure comes in competition with all similar associations, and it should not be behind others in the inducements extended and in the facilities for improvement and enjoyment provided for its membership.

Fifthly. The engineering profession, growing in dignity and importance, as it is from year to year, demands suitable acknowledgement at the

hands of its friends. We live in a distinctively scientific age; our unprecedented progress in wealth and power and all that goes to make up our modern civilization is directly due to that control of the forces of nature which engineering has given us. Engineering makes all other sciences tributary to itself, and marshalls all branches of knowledge into a grand army for works of beneficence and conquests of peace. The renowned knights of old were not more chivalrous in defense of the weak, nor more self-sacrificing for the sake of truth and right, than are the engineers of to-day; generals ordering forces compared with which the armies of the ancients were insignificant and contemptible. The machinery of the universe is at their command and swift to execute their bidding. The headquarters of such a staff should be in keeping with their high commission; halls where should be gathered the trophies of bloodless battles and the records of past achievements, legacies of inestimable value to those who follow and stimulating them to still greater victories.

In conclusion a word will be permitted as to the possible form of a truly National Engineering Society. It must not trespass upon the autonomy of the local organizations—it must not be wholly independent of them; rather it should be in close touch and sympathy with them, enjoying their moral support and conferring certain professional benefits in return. Such a society can only be a representative body, its members delegated from the several local organizations under proper restrictions; a permanent institution, constantly recruited by the choicest material in the local membership, and dealing only with questions of broad and general import, which are in the nature of things beyond the scope of any local society. Such a body would be in harmony with the spirit of all our American institutions; it should be chartered by the government, and to avoid all local jealousy should have its headquarters at Washington. For concentration of brain and ability, it would command the highest respect and in its achievements might well challenge the admiration of the civilized world.

But while we wait for the coming of this ideal body, let us not neglect our own modest Association of Engineering Societies, which is at least a step in the right direction, and which is capable of far more beneficent service than it has yet been permitted to perform. It is a mistake to look upon it with suspicion and to be jealous of its powers. Its function is only such as the constituent bodies may prescribe; it is eminently their servant not their master. Its possibilities for good are very great if properly availed of. Our Club is to be congratulated on its increase of membership which has doubled the representation to which it is entitled in the Association; and we should therefore stand ready to further any scheme increasing the usefulness of the general body. The coming of the Columbian Exhibition will furnish a fitting opportunity for its effective action.

In taking leave of the chair with which you honored me a year ago, I beg to express my appreciation of the warm sympathy and cordial support which I have uniformly received in my endeavor to execute the duties of the office and suggest new lines of policy to the Club. I only regret that absence from Cleveland of late has prevented me from serving

you as I would wish, or of enjoying the privileges of the Club which I highly appreciate.

It affords me pleasure to turn over the office to so worthy a successor, who has ably seconded my efforts during the past year, and I do so in full confidence that he will lead on the Club to greater success and renown than it has ever yet achieved.

SOME NOTES ON DISTRIBUTION RESERVOIRS.

By W. W. Curtis, Member Civil Engineers' Society of St. Paul.

[Read November 3, 1890.]

One of the most important of the many important questions arising during the construction or designing of a water supply system is that of arranging some means for the storage of water during greater or less periods of time, to equalize the work on the conduit or pumps, and to provide for cessation of supply during the night, or during shut downs for repairs; and the questions which naturally arise are those concerning the necessary capacity, and the methods and details of construction of reservoirs for these purposes.

During the year just passed, while designing and constructing work of this nature, I was induced to look up the subject a little more carefully than I had done previously, and offer you some of my results, as to the general practice and my conclusions.

Naturally the first question is as to the capacity required, and this is dependent upon several conditions. The first and most important would relate to the character of the water; whether it be from underground, deficient in oxygen, and the probability of its developing large organic growth upon exposure to the air. It is curious to note the manner in which we are in so many ways reverting to the customs of the early centuries. The water supplies of the long since decayed civilizations were stored underground, whether by choice or from necessity we know not. To cover our water, here, has not been considered necessary, and only of late years has much thought been given to the subject. The presence in certain waters, however, of organic growths which, while not offensive while living, yet in their death and decay make the water offensive to taste and sight if not injurious to health, has made itself felt. The only remedies for this trouble so far discovered are aeration and protection from the light, and of these the latter, except perhaps for very large plants, is more efficient as well as economical.

The English practice has for years been forced to covered reservoirs, not so much apparently on account of the growths in their water as from the great amount of soot and smoke in their atmosphere. An act of Parliament passed in 1852 requires all reservoirs within five miles of a certain

portion of London to be covered,—and as London is supplied by quite a number of companies, this means more than it would here.

As supporting the very general concensus of opinion that spring or underground water should be protected from the light may be cited the opinions following:

Thomas Hawksley, in 1852, testified before a committee that water taken from the new red sandstone was particularly liable to growth of Algae if exposed to the sun, but that the exclusion of light and heat was a complete preventive. He had previously recommended covering a reservoir at Liverpool for the same reason.

Mr. G. H. Parker in a report to the Massachusetts State Board of Health, states that the town of Brookline being troubled by an offensive taste and smell in the water, covered the tank in which the water was stored, with complete success.

Mr. F. P. Stearnes says: (See N. E. W-Wks Journal for Mch., 1888). "I think this is a matter worthy the attention of engineers, and I think if they look into it the result will be they will not build any more open reservoirs for ground water.

Mr. J. J. R. Croes in his report on the proposed supply for Syracuse, N. Y., speaking of the water pumped from the driven wells, says:

"But if this water should be considered fit to use, it would be necessary to pump it directly into the mains and not allow it to be stored in an open reservoir, for the invariable experience of all towns which have been supplied from underground water is, that it rapidly becomes foul and offensive and swarms with vegetable growth, when exposed to the air in open reservoirs. It must be used quickly, just as it comes from the ground." To this I would add and I infer Mr. Croes would also, "or stored under cover."

If this idea be carried out, it will make necessary that the reservoirs be reduced to the smallest possible dimensions, to save the heavy cost of roofing space unnecessarily.

Secondly, the safety of the supply. If the water is pumped, the ratio of the total capacity of the machinery to the daily consumption—the amount of reserve power to allow for repairs that may be necessary; and in small cities, to permit the pumping to be done in ten hours. If the supply be by gravity, the safety from interruption by washouts, breaks, etc., of the conduit: length of time required for cleaning and repairs,—the problem resolves itself into an equation, one side of which is the cost of increasing the size of the reservoir, the other, the cost of increasing the pump or conduit capacity. As the *Engineering News* editorially pointed out in commenting on some work recently illustrated in that paper, there is a point where it becomes false economy to have expensive machinery and not use it to something like its full capacity. If the pumping machinery is an expensive, high duty plant, it is foolish to let it lie idle unnecessarily one-half the time—and while with growing cities it is hard to get anything too large for the future; it is better to get now what is needed and keep the capital and interest saved to invest in duplicate machinery when needed.

Thirdly, the population to be served; suitability of the location,

materials at hand and financial ability,—all these must be considered, and for each case given their proper weight. The old rule arbitrarily determined was to provide a supply sufficient for from five to ten days use, based upon the total population. This rule is perhaps as good as any general one can be, and the lesser limit with good water of such quality as to be unaffected by exposure and all other conditions favorable, would give a maximum size, sufficient for all reasonable contingencies. In a city of an assumed size of 10,000 people, this would call for a reservoir, assuming 100 gallons per capita, of 5,000,000 gallons capacity. As the usual amount of water used even in very large fires is small; this capacity, as before remarked, would be considered a *maximum*.

Mr. W. B. Sherman in a paper published in the N. E. Water Works Assoc. *Journal* for Dec. 1888, gives considerable data as to the amount of water used at very large fires, from which the following is principally abstracted:

Providence. R. I., Feb. 1888. 2,000,000 gallons; maximum per hour not less than 241.000.

Norfolk, Va., for the years 1881-2-3, when population was about 60,000, the total amount used for the years were 2,000,000—500,000—1,300,000 in round numbers, the average amount used at each fire for each of the three years being between 50,000 and 60.000 gallons.

At Fall River, Mass., prior to 1887, the greatest fire ever experienced required 3,000,000 gallons.

The very recent great fire in Lynn, Mass., used about 8,750,000 gallons.

The perfection to which pumping machinery has been brought, and the evidence given by direct pumping plants of the ability of machinery to alone protect life and property, makes safe and justifiable the reduction of this storage very considerably, where necessary. The margin of safety should increase with the size of the interests at stake, and the dependence of those interests upon the efficiency of the works.

If the city is small and the water must be covered, sufficient for twenty-four hours consumption, and an ordinary fire, would be very satisfactory.

Reservoir wall may be of two materials, used separately or conjointly, —masonry and earth. Either is sufficient in itself to satisfy all demands, and generally speaking, it is better to use either rather than both, in the same bank. Homogeniety is an essential for water tight constructions, and it is difficult to secure this with two such distinct substances in the same wall.

The great majority of reservoirs are built of earth, and those in the future will probably in the main be like them. It is believed, however, that there are many cases where it would be possible to use masonry at no greater expense and with very considerable advantage. There are certain points of superiority in the use of masonry,—less area of land required, the walls being thin, as compared with the thickness necessary in earth, and almost vertical,—less chance of dangerous deterioration from lack of proper maintenance, and the greater ease with which it can be roofed.

It is probable the near future will see very considerable deviations

from past practice in the use of masonry in this line of work, especially where it is necessary to protect the water from the light.

The circular form is that which for the least length of wall gives the greatest cubical contents and is accordingly theoretically the most economical. This is borne out practically also in a masonry construction, unless modified by the manner in which it cuts up a rectangular piece of land; or in case it is to be roofed over, under ground. In the latter case it complicates matters and is not advantageous. It would necessitate the use of iron beams to support the roof arches, or a secondary set of arches built concentrically with the walls.

The circular plan reduces the amount of masonry required, as it is possible to consider the walls as an arch and proportion them for arch pressure, instead of as a retaining wall for the exterior pressure.

If the reservoir is covered over with a permanent load of earth, the rectangular shape lends itself much more readily to an economical design for the roof, and as the pressure of the roof arches prevents the failure of the wall by rotating about its inner toe, it is proper to reduce its thickness quite materially, from that usually used for retaining walls of the same height.

The question will naturally arise as to the accuracy of considering a circular wall as an arch, when the bottom is held, as in the case of a reservoir, and the limiting radius for which it is safe. This subject has been quite thoroughly discussed in connection with the Quaker Bridge Dam. The general conclusion has been favorable to the curved form under all circumstances, and that it is safe and right to depend upon arch action when the radius is not too great. Church, in his report on the Quaker Bridge Dam, quotes the following opinions as to the radius beyond which the dam will no longer perform the functions of an arch.

Pelletreau, length of dam 131′.

Delecro, when the thickness of the arch would equal $\frac{1}{3}$ the radius.

Krantz—65.6′.

The Board of Experts in their report on the above mentioned works, say:

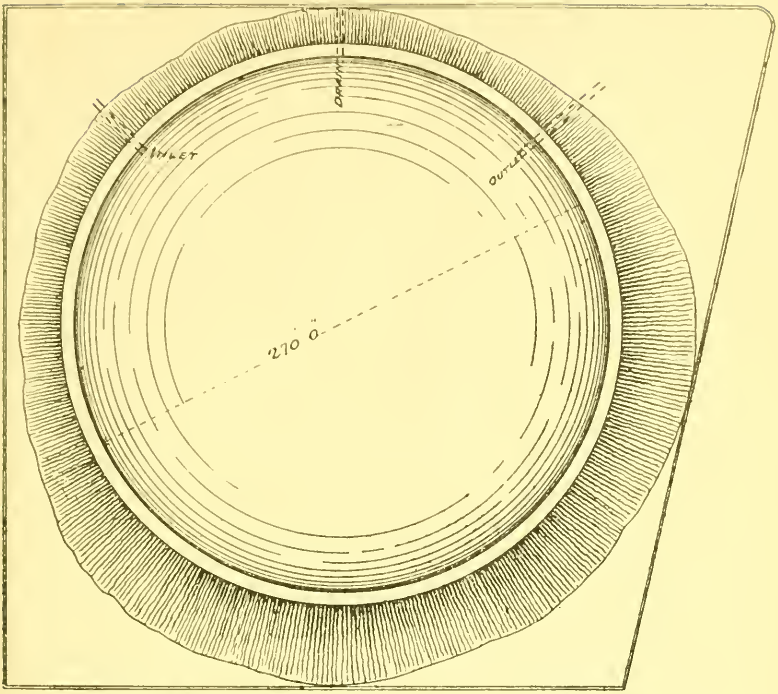
"That in designing a dam to close a deep, narrow gorge, it is safe to give a curved form in plan and to rely upon arch action for its stability; if the radius is short, the cross section of the dam may be reduced below what is termed the gravity section.

In a general way we would speak of a radius under 300 ft. as a short one, and of one over 600 ft. as a long one, for a dam of the height herein comtemplated."

It is important, however, to remember that the opinions refer to high dams, while for distribution reservoirs they would naturally be low. This would decrease the maximum radius allowable, so that the limits above are perhaps more interesting than valuable.

Plans of quite a number of reservoirs with masonry walls, will be found in Humber's Water Supply, several of them being covered. One of them is reproduced, as built at Aberdeen, Scotland.

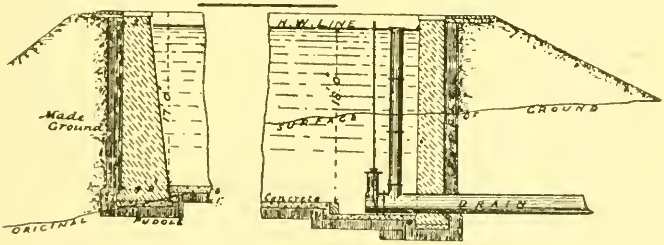
The Trans. A. S. C. E., of August, 1889, contains illustrations of the



LOW SERVICE RESERVOIR AT BRAE OF PITFODELS.

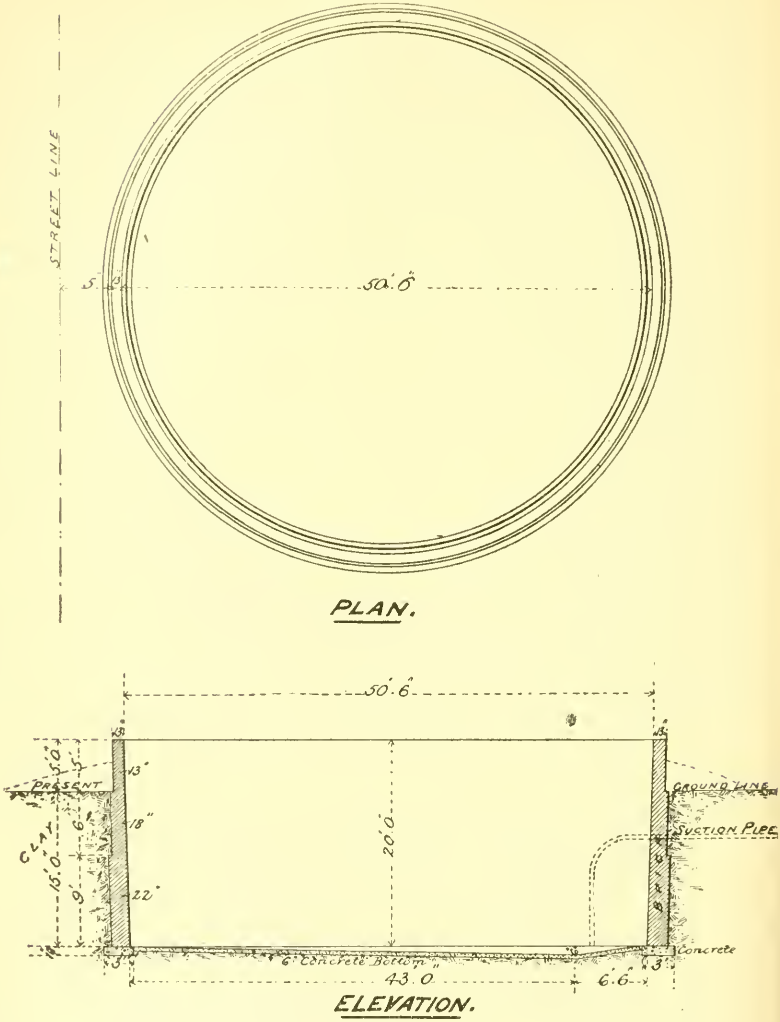
ABERDEEN.

— CROSS-SECTION —



From "HUMBER."

Vicksburgh settling basins, the walls of which are of brick. A plan of an open reservoir built by myself at Monmouth, Ill., while without any special merit, is submitted because there are so few illustrations in current literature of a not uncommon construction, which could well be used much oftener than it is. The reservoir at Pierre, Dakota, illustrated in the *Engineering News*, of June 21, 1890, is a much bolder design, being 150′ in diameter with walls 25′ high and only 2′ thick, built apparently of



Reservoir for MONMOUTH, ILL., WATER WORKS.
Designed by W. W. CURTIS, ENGINEER.

rubble masonry. This wall figuring the total pressure of the prism of maximum thrust with the reservoir empty, as distributed over the entire height of wall, has a pressure on it of nearly seven tons to the square foot of cross section, due to arch pressure.

Of underground reservoirs, in this country, there are not a great many examples. Mr. J. J. R. Croes designed one for storing rain water for the Lawrenceville school, as illustrated in the *Engineering Record.*

I built one for the city of Hudson, Wis., a few years ago, patterned somewhat on Mr. Croes, which will be found illustrated in the *Engineering News*, of March 15, 1890.

Illustrations of a great many reservoirs of various kinds will be found in the engineering journals and also in the volume on Water Power of the 10th Census Report, as well as in the various City Reports.

The reservoir at Monmouth, Ill., was constructed of a very hard brick, almost or quite vitrified, laid in cement. This is greatly superior to any stone work to be had at reasonable prices, both in impermeability and strength. If it is necessary to use stone for such a wall, it should be lined with brick work, with a good thickness of mortar between.

Humber illustrates a few examples of circular reservoirs underground, built in England, but it was necessary to support the roof with iron beams, —a construction which hardly strikes us as desirable. The desire, probably, to avail of the inherent theoretical economy of the circular form has caused a few instances of reservoirs with earth banks to be built in this way. The practice would hardly seem desirable, however, as the difficulty of building the walls to the proper lines would be considerable, and with the disadvantageous use of the ground would perhaps offset the apparent advantages.

With earth banks, if a rectangular plan is adopted, it is necessary to join the planes of the sides by curved surfaces, to permit the roller to make the turns at the corners. Unless the radius at the top is about 5′, the roller cannot be turned at corners without trouble and without failing to roll part of the bank.

The slope necessary to be given to the banks seems to be somewhat an open question. English practice, as given by Humber, is to make the inner slope against which the water stands, three to one, and the outer, two to one. In this country we find the slopes to vary from three to one, to one and a half to one,—without any apparent reason for the variation.

In the case of reservoirs which, from their size, would seem to come more nearly under the head of storage than distributing reservoirs,—where the wind has an opportunity to produce heavy wave action, the additional slope is no doubt needed, although, even here Mr. McAlpine recommends only 2 : 1, both inside and out. Then the character of the face covering affects the slope somewhat. The old, and often the present practice is to build the inside slope of quite permeable material and cover it with broken stone and stone paving. It seems difficult to conceive of any better method of inviting the water to saturate and soften the bank; and to prevent the saturated earth from taking its natural slope, to the destruction of your lining, it is probably necessary to build to that slope in the first place.

The later, and to my mind the better practice, is to make the facing to the sides, of concrete of such quality and thickness as to insure that the water which will percolate through it into the bank will be too little in amount to more than moisten it.

It is essential that the banks of the reservoir be as nearly impermeable as possible, that they fulfill their duty; and to secure this the earth must

have a certain composition as regards fineness. The banks have another office, however, besides that of preventing the water seeping through them,—that is, they are obliged to retain the water in a body as well. To do this the banks must have weight, and the ideal material would be that which for the maximum of weight per cubic foot had the smallest voids in it. The ability to prevent percolation of water is dependent solely upon the number and size of the spaces between each separate particle of earth. If we make an artificial mixture to meet these conditions. according to Mr. Fanning, we will require about the following:—

Coarse gravel....................	1.00 yard.
Fine gravel....................	.35 "
Sand....................	.15 "
Clay....................	.20 "
Total....................	1.7 yds., equal to 1¼ yds. when packed.

I think the conclusion that one naturally draws from reading most books on the subject is that clay, of an exceedingly good quality in large quantities, is a necessity to good construction. It is necessary that we have some fine material to mix with the coarser, and clay from its cohesiveness and fineness is superior to all else; but good loam is nearly as effective for the purpose as clay, and in some respects is superior. Pure clay from its tendency to crack when dry and swell when wet, and for one part of it to slip on another, is exceedingly dangerous unless used judiciously. The difficulty of breaking it up as we usually find it, into a powder, as it is necessary to do to thoroughly mix it with the other materials, if we use it in a mixture, renders very close watching necessary if it is proposed to secure a close intermixture of the various materials.

Loam is a mixture of sand and clay, and if not too deficient in clay will answer every purpose and be much more easily and cheaply handled. Rankine says: "The proper material for puddle is clay, containing as much sand and fine gravel as is consistent with its holding water; if there is too little sand the puddle is liable to crack in dry weather."

Mr. Comoy, Inspector General of Ponts et Chaussees in a "Report on Various Methods of Consolidating Earth That Has Slipped," reprinted in the *Engineering News*, of 1877, says: "Argillaceous soils are but little adapted to this kind of work. They are unsuitable, in that in the course of time they allow water to penetrate, no matter what may be their compactness; and on the other hand it is difficult to ram them thoroughly; for these soils, which are very firm when dry, become very slippery when wet, and at such times there is much difficulty in ramming them.

The soil that should be preferred for the construction of reservoir embankments is that which is chiefly composed of silicious sand with at most from 25 to 30 per cent. of clay.

Earth in which clay predominates seems to me so defective for making reservoir embankments, that if I had only this kind of earth at command

for building such a work, I would give up this method of construction and adopt a masonry dam."

Mr. Fanning, speaking of the reservoir at Manchester, N. H., says:

"This has demonstrated, to the satisfaction of the writer, that very fine sand may replace, to a considerable extent, the clay that is usually demanded, and his experience includes several examples, among which, on a single work, is more than three-fourths of a mile of successful embankment entirely destitute of clay, but sand was used with the gravel, of all grades, from microscopic grains to coarse mortar sand, and a sufficiency of loam was used to give the required adhesion."

The ideal bank would be one built entirely of a gravel with its interstices filled to the maximum degree with fine sand and clay; containing the most gravel and the least clay possible, and still have the voids a minimum. It would be a concrete with clay for the matrix. The entire bank would be of the same material rolled to the same degree, resulting in a bank homogeneous and free from danger of unequal settlement. If it is impossible to secure a sufficiency of fine material for the entire work, the next best thing would be to use for the outer slope broken stone or other coarse material. If fine material sufficient for this even, cannot be secured, it will be necessary to resort to a core wall of some kind. The use of a core cannot be commended, however, and the presence of two different materials endangers unequal settlement and longitudinal and transverse cracks.

Distribution reservoirs differ from storage reservoirs in this essential particular,—they are not subject to overflow from uncontrollable floods; and this difference makes wise a radical variation in construction. Rather than use a core wall of puddle or masonry, is it not better to place this material on the face of the bank? This will be spoken of again when considering the question of inside facing.

Whatever the material, two things are essential,—that the foundation be secure from settlement and percolation of water through it, and the bank be thoroughly wet and rolled, and that all loose and perishable material is removed from the site.

As an instance of the futility of trying to make a tight piece of work on a bad foundation, may be cited the distribution reservoir at Newark, N. J., as described in *Engineering News* of August 9, 1879.

If the foundation is secure from settlement, but is underlaid by a permeable strata, to which the water will have access it will be necessary to cut off the passage of water through this by excavating to solid strata and refilling with puddle or concrete, or driving sheet piling. It will not be attempted to go into this part of the subject, as it is a contingency not often arising with distributing reservoirs, and from my inability to add anything to the already existing data. It is suggested, however, that the proper place for such work is the toe of the inner slope, rather than the center of the bank.

The banks should be so joined to the original surface as to prevent any percolation along the line of the bottom of the bank. If the new material is of a different character from the natural earth of the site, it is well to

open up a trench into the surface of the foundation and refill it with the material used in the banks.

The rollers ordinarily used weigh 1000 pounds per lineal foot and require four horses to haul. The water is best furnished under pressure, so that it can be delivered where wanted through hose. In the recent construction of a two million gallon reservoir, I laid a line of 1½″ pipe 4,000′ long to the work and ordinarily carried on it about 40 to 50 lbs. pressure above the static head. This would correspond to the use of from 2 to 2¼ cubic feet of water per minute. The pipe at the work was carried clear around the reservoir and connections for hose put in at each corner and at the midway points.

Where large amounts of clay are used in the bank, or clay must be mixed with other materials, grooved rollers will work the materials together and make a more solid bank than the smooth ones; but if the earth contains the right proportion of fine and coarse material naturally, the smooth roller will pack it the better.

The old theory of building a dam was to construct a clay wall to hold the water, then on and around that place porous earth to the depth to which the frost penetrates, and upon this on the water slope, broken stone and stone paving to prevent wash and the cutting of the banks by musk-rats and eels. The result of this is illustrated by the case of the New Bedford reservoir, as stated by Mr. R. C. P. Coggeshall in a paper published in the journal of the N. E. W. Works Association, of June, 1890. Built of earth 15′ wide on top with slopes of two to one. The bottom is the natural surface as excavated, and is of gravel well filled with clay. The banks are 20′ high and water 18′ deep. Capacity fifteen million gallons. The facing was of stone placed on gravel. After twelve years use, the wall of packed stone became badly broken, the gravel having washed out from behind it. It became necessary to draw down the water and repair it, when they grouted all the joints and have had no further trouble. The failure at Lowell is onother instance of open facing. When drawing the water out for cleaning purposes, the paving and puddle lining came also. The puddle was found to be thoroughly saturated with water, so that it could be properly called mud. When repaved the paving was set in cement.

Mr. Samuel McElroy in a paper read at the Eighth Annual Meeting of the American Waterworks Association, has expressed himself so fully on this subject that I will quote from him. Speaking of the reservoirs at Brooklyn, he says:—

"With the best material for earthwork at hand, and a small deposit of clay within the grounds, the pondage lining was the next study; and here there was no question that the practice of the ancient engineers with works in use to-day, and of the best modern examples was in favor of water tight faces.

Of the 27 reservoirs in London, 21 were lined with substantial brick masonry, except occasional cases of small basins with concrete slopes. This plan was adopted at Philadelphia by Mr. Graff and in other cases; and at Albany, on the Erie Canal, and elsewhere, I have seen the evils of

dry stone work too clearly to adopt it here. Yet dry stone protection was the rule of the day, and is very much used yet.

Elevated service reservoirs are always dangerous structures in any locality, and engineers who have had to measure the damages caused by rupture, know how appalling they may sometimes be. If their safety depends on the proper confinement of a large body of water, which is incessantly at work against its walls, and earth banks are depended on to guard it, it must not be permitted to act on so soluble a structure. The only way to protect an earth reservoir bank or floor is to keep it dry; otherwise pressure, storm wash, motion, leakage, frost or animals may weaken and destroy it. The usual one and a half to one slope is far from being an angle of repose for an earth bank, and to stand water wash it needs to be four or five to one."

The facing par excellence in my estimation is concrete with offsets to obviate danger of slips. If the bank is of very open material it will be necessary to back the concrete with puddle, but I would prefer to use the same amount of clay incorporated into the first 5′ of the bank back of the facing. This concrete can be covered over if desired with brick, as being less easily affected by frost and wash,—and if in a very cold climate, the concrete might be carried back into the bank a few feet. This, however, I would not be prepared to adopt at present for my own work.

If frost is to be feared, I am inclined to think all damage could be avoided by placing the concrete on the face of the bank, up to low water level or a few feet below it, then offsetting back sufficiently to leave a space back of the plane of the face for a thin covering of asphalt and a brick wall laid in cement with close joints; the asphalt being between the concrete and bricks. With good Portland concrete finished with a mortar face, I doubt much if there is any danger of frost doing any considerable injury, but by the greater impermeability secured by the coating of asphalt protected from wash by the brickwork, any such danger would be greatly reduced. I believe Mr. J. D. Schyler, M. A. S. C. E., proposes using an asphalt facing for the great earth dam now-being constructed for the Citizens Water Co., of Denver, without any covering to prevent damage by wash; and it is possible such a mixture may be secured as will give the necessary hardness without danger of cracking under the extremes of temperature.

The bottom should be covered with concrete or brick, and puddle can be used under it to good advantage if the earth is very porous.

The subject for which I have claimed your attention for a little while is a large one, the practice more varied than it would seem reason would warrant, and I can only hope that my effort to record my own ideas will induce others to do likewise, that we may discover our errors and so secure more value for our work and for our client's money.

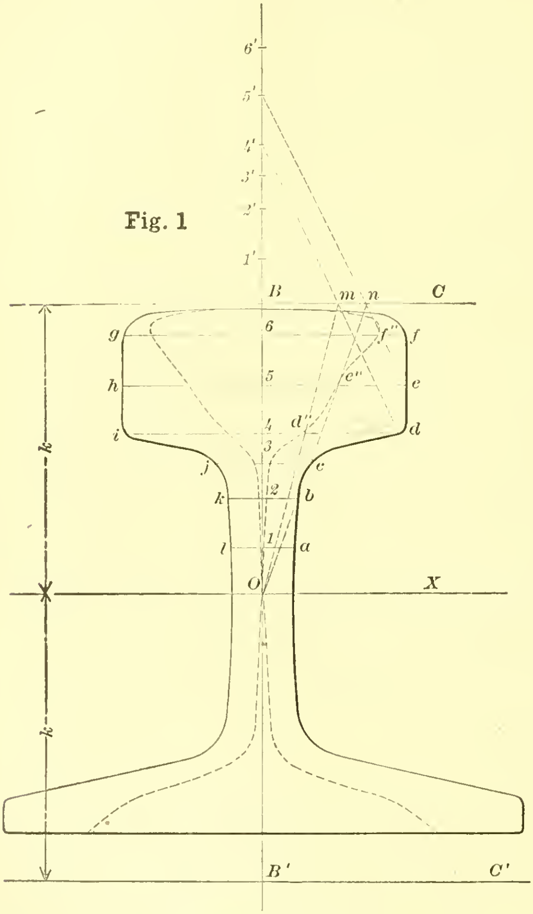
A SIMPLE GRAPHICAL METHOD FOR DETERMINING MOMENT OF INERTIA.

By F. E. Turneaure, Member Engineers' Club of St. Louis.

[Read Feb. 18, 1891.]

The following graphical method for determining the moment of inertia of an area about any axis, the writer has never seen published, and,

Fig. 1



believing it to be new and of some value, ventures to present it with a brief demonstration.

The method consists essentially in the measurement, in most cases, of a single area easily constructed, and with the aid of a planimeter is very

rapid and accurate. For the sake of clearness we will consider two cases.

1st. When the moment of inertia is desired about any given axis.

2nd. When the moment of inertia is desired about an axis through an unknown center of gravity.

1st. Let it be required, for example, to determine the moment of inertia of the rail section, shown in Fig. 1, about any given axis as OX. The actual operation would be as follows:—

For the upper portion of the figure draw any line OB, perpendicular to OX, and, at some whole number of units k, from OX, draw the parallel BC. Draw also any number of lines through the given area parallel to OX, as la, kb, jc, etc., spacing them closer where the outline is irregular than

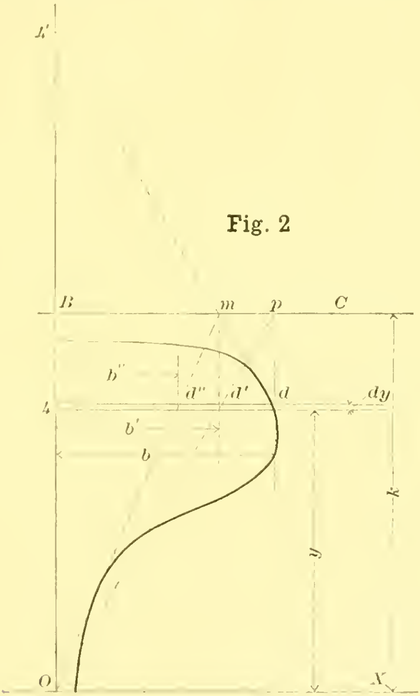


Fig. 2

where regular, and lay off $B1' = O1$, $B2' = O2$, $B3' = O3$, etc. Then for the point d, say, draw $d4'$ intersecting BC in m; then Om, thus determining a point d'' on $4d$. In like manner find points e'', f'', etc., corresponding to e, f, etc., and join the new system of points by a smooth curve. The oblique construction lines need not of course be actually drawn, the required intersections only being marked. The new curve for the lower portion is likewise constructed, using a line $B'\ C'$, at a distance k, *below* OX in place of BC.

Then if A'' represent the total area of our new figure above and be-

low. and I_{ox} the required moment of inertia, we shall have,

$$I_{ox}=k^2 A''.$$

Demonstration. The general expression for moment of inertia about an axis OX is

$$I_{ox}=\int b\, dy\, y^2,$$

where b = length of strip parallel to OX, dy, its width, and y, its distance from the axis. If k is a constant we may write

$$I_{ox}=k \int \left(b\frac{y}{k}\right) dy\, y \qquad (1)$$

$$=k^2 \int \left(b\frac{y^2}{k^2}\right) dy \qquad (2)$$

Referring now to Fig. 2, let md' be drawn parallel to OB and then Op through d'. Then since $O4 = B4'$ and $Bm = 4d' = b'$, we have $Bp = 4d = b$. Therefore by similar triangles

$$\frac{b}{b'}=\frac{k}{y}, \text{and } \frac{b'}{b''}=\frac{k}{y}. \qquad (3)$$

Multiplying we get $b''=b\frac{y^2}{k^2}$. The above construction being carried out as in Fig. 1, for each horizontal strip, we have by substituting in (2),

$$I_{ox}=k^2 \int b''\, dy$$
$$=k^2 A'' \qquad Q.\ E.\ D.$$

If OB can be made a line of symmetry it will be necessary to construct but one-half of the new curve; also k should be made of such a length as to give a fair sized area to measure and at the same time good intersections.

2nd. This case can usually be reduced to the first by determining the center of gravity from considerations of symmetry, or by cutting out the section from thick paper and balancing on a knife edge. Where this cannot readily be done as in the case of disconnected parts, we may proceed thus:—

Assume an axis oX, Fig. 3, parallel to the unknown gravity axis and construct the area A'' as before; also at the same time project the points m, n, p, etc., down upon their corresponding horizontal lines, thus fixing points c', d', e', etc. Join these also by a smooth curve and let A_1' be that part of the area of this new figure above the axis, and A_2' the lower portion. Only the upper right hand portion is shown in Fig. 3, but the given area may be of any shape and the line OB drawn anywhere. As before we shall have $I_{ox} = k_2 A''$. If now A represent the total original area, we have, by taking moments about OX,

distance of center of gravity above $OX=d$

$$=\int \frac{b\, dy\, y}{A}$$

$$=\frac{k\int \left(b\frac{y}{k}\right) dy}{A}. \qquad (4)$$

From (3), $b'=b\frac{y}{k}$ and considering y negative below the axis, $\int b'\, dy = A_1'—A_2'$. Substituting in (4) we then have

$$d = k\frac{A_1' - A_2'}{A}.$$

I_g being the required moment of inertia about a gravity axis we have,

$$\begin{aligned} I_g &= I_{ox} - d^2 A \\ &= k^2\left[A'' - \left(\frac{A_1' - A_2'}{A}\right)^2 A\right] \\ &= k^2\left[A'' - \frac{(A_1' - A_2')^2}{A}\right], \end{aligned}$$

in which the areas to be measured are, A, the given area, and A' (A_1' and A_2') and A'' the two "constructed" areas.

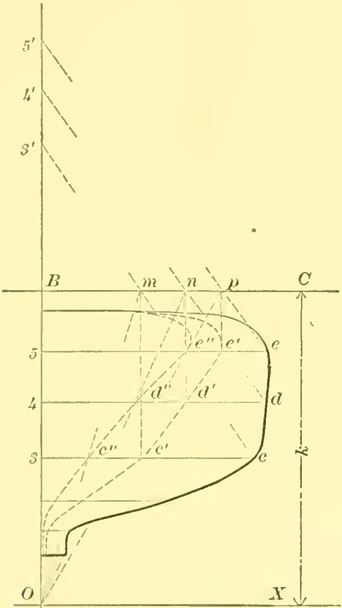


Fig. 3

If desired the area A' may be first constructed and the center of gravity located, then a new axis taken through it and I_g determined as in the first case. The first part of this construction then would give us a method for finding the center of gravity of a figure without considering the other part of the problem.

Considered as a section through a loaded beam, it is interesting to note that if we make k equal to the distance to one extreme fibre, taking a gravity axis, our area A' will be such that if a *uniform* stress of the same intensity as that upon this outer fibre were applied, the resulting moment would be the same as that upon the section. This relation is fully discussed and used to some advantage in finding moments of inertia in Sir Benjamin Baker's "Strength of Beams," the above method being in the main an extension and simplification of the one there given.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

CIVIL ENGINEERS' CLUB OF ST. PAUL.

JOINT MEETING, APRIL 6, 1891.—Third Joint Meeting of the Engineers Societies of St. Paul and Minneapolis was held at Hotel Ryan at 8:30 p. m., April 6th.

Mr. F. W. Cappelen read a paper on the Minneapolis Suspension Bridge.

The first bridge across the Mississippi river was a 560 ft. suspension span built in 1854 and replaced by the structure under consideration in 1876. The second bridge was taken down in 1889 to make room for the present steel arch bridge, the wood work being completely wrecked by dry rot.

The cables were removed wire by wire, each one having been pulled from its place and coiled on a drum by steam power, at an average cost of 204 dollars per wire, or a trifle more than $^4/_{10}$ of a cent per lb.; 1,421 miles of wire were thus wound.

Mr. Cappelen next demonstrated that the loaded cables assumed the form of a parabola instead of the catenary.

The cost of demolishing the $200,000 structure was $11.000. The anchorage irons although embedded in cement were found deeply corroded.

Discussion of the paper brought out the fact that wooden trusses of this day and vicinity are built of green lumber, which should not be painted (except at the joints) until thoroughly seasoned; and that oak keys used in pine timbers may be wrapped in tarred paper to advantage.

Adjourned. C. L. ANNAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

279TH MEETING, MARCH 4, 1891.—The 279th meeting of the Society was held at its rooms, Wednesday evening, March 4, 1891, at 8 p. m. President L. E. Cooley in the chair and 50 members and visitors present.

The reading of the minutes of the last meeting was dispensed with and the Secretary, for the Board of Directors, reported the following gentlemen elected to membership in the Society:

James P. Mallette, E. T. Eriksen, Archibald R. Eldridge, George M. Huss, Oliver W. Child, Frank H. Cooley, Elam Gray, Alfred C. Schrader, Geo. W. Sturtevant, Jr., John Fraser.

The following applications were also filed:

Edward O. Reeder, Chas. E. Laas, Arthur G. Baker, William F. Hogan, Nelson O. Whitney, James C. Hallsted, Howard N. Roberts, A. U. Leonhaeuser, Thos. Appleton.

A letter was read by the Secretary from the Boston Society of Engineers, inviting the officers of this Society to their annual meeting.

Mr. Richard P. Morgan, chairman of the committee on "Terminal Facilities, etc.," reported that the committee have made very satisfactory progress since the last meeting of the Society. They have received a very considerable amount of valuable data, and important computations have been made in respect to the working of the committee.

Mr. W. J. Karner, for the "Committee on Badges," stated that they had held one meeting, but in consideration of the fact that a change of name was coming up for discussion, he would suggest that no definite action be taken until that matter was decided.

President Cooley then said:—At the last meeting the general subject of committees was brought up. I believe there are one or two committees that have not been active, and one or two that have done nothing. In regard to the committee on Municipal Public Works, that committee is in fair shape, I think, to go ahead with the purpose for which it was organized. In regard to the committee on Sanitary Engineering, the Secretary has corresponded with several members, but nothing has been done yet; it is anticipated they will be able to report something for the next meeting of the Society. In regard to the committee on Topographical and Cadastral Survey for Illinois, the Board of Directors have concluded to reorganize and reappoint the committee, and I have to announce, therefore, as the new committee upon that subject, Messrs. H. B. Alexander. C. McClellan, Bernard Feind, F. C. Rossiter and Charles Hansel. The Illinois Society of Engineers and Surveyors is taking some action through a committee appointed for that purpose, looking to some action with the Legislature. They have a committee appointed to consider the question of a topographical survey of the State. I understand the State Board of Agriculture is interested in the matter, and also the Engineer of the Railroad and Warehouse Commission. I think it would be proper, unless there are some objections, for this committee to co-operate, so far as may be in its power, in forwarding any of these objects in connection with these other agencies, without going to the extent of committing this Society to any definite line of action in the premises. If there is no objection, the committee will be so instructed. I believe that is all, so far as these old committees are concerned.

The president then called for new business or any matters it might be desirable to call up.

Mr. E. L. Corthell said:—Mr. President, I have no business to propose, but there are one or two matters that informally I would like to present. First, in regard to our project for an International Engineering Headquarters and International Congress at the Exposition. When I was in Mexico last, a few weeks ago, I spoke to Mr. Fernandez Leal, who is the President of the Mexican Society of Engineers and Architects—he is also the chief official of the Department of Public Works—in reference to this matter. He was much interested in it, and gave me assurance on behalf of his society that they would co-operate with us in it; they would do every thing that they could in Mexico as engineers to make our project a success. He also wished me to be the bearer of an official message from him as President of that Society to this Society, that beyond the temporary connection that they might have with us in assisting this matter, they would like to become regularly associated with us as correspondents, that is, to exchange proceedings and transactions, and to have it considered as a permanent connection in the way of correspondence. The Mexican Society of Engineers is composed of quite a number of Mexicans, and I think some American and English Engineers with them, and have considerable influence I think, as engineers, in Mexico. They take a great deal of interest in their Society, as the proceedings, which have already been sent on, will show, discussing questions of engineering interest technically, and subjects at they are particularly interested in; such subjects, for instance, as the drainage of he Valley of Mexico, papers on Vera Cruz harbor—subjects of that kind, both of national and local interest. Mr. Corthell then touched upon his paper on "An Enlarged Water-way between the Great Lakes and the Atlantic Seaboard, an abstract of which is given in this issue of JOURNAL with some of the discussion.

The President said: The subject is one of great importance to the city and might properly be made the topic for our next meeting. I think there are several of the members that would express some useful views on that subject. The Society is certainly interested in the matter, and I hope that the paper may be distributed with a view of having a full discussion of the subject when this summary is presented, and that all the matter can be printed in our Society JOURNAL so that it can come before the people. It is of great importance in a wide sense.

Mr. T. T. Johnston then offered the following:—

Resolved, That a committee of three on Permanent Quarters be appointed to consider and recommend more adequate provision for the Society and what may be practicable in the way of a permanent home.

The resolution was put and carried.

The President, later, appointed the following committee: Messrs. Chas. MacRitchie, O Guthrie and Henry Raeder.

Mr. Isham Randolph presented the following resolution, which was put to vote and carried.

Resolved, That the Board of Directors take such steps as may be expedient, in co-operation with any other public agency, to secure a legislative commission, having for its object the maturing of better provisions in the interests of improved highways in the State of Illinois.

The President said:—I would say in regard to that, that citizens presented a resolution for the appointment of a legislative committee with a view of maturing some general law, or some better law than now exists in regard to highways—public highways—especially country highways, following the lead of legislation which has brought great fruits in the States of Tennessee, Kansas, and others, and I think it is a very meritorious proposition. I think the Illinois Engineers and Surveyors are taking some action in aiding the appointment of such a commission to sit during the recess of the legislature. I do not understand that Mr. Hansel wants anything more from us than an expression of opinion—whether we think our country highways can be bettered or not.

Mr. Corthell upon being called up by the President, said: You will remember that several months ago I read a paper on the subject of a monument to Captain Eads. Since that time the Monument Association has perfected its organization, and circulars have been sent out to about two thousand engineers and others who were friends of Captain Eads, or who knew him during his lifetime, not only in this country, but in other countries, Mexico, South America and Europe, and I understand that responses are being received which are gratifying. The object of the Association you already know. I have a letter from Col. Meier of St. Louis, who is the Secretary of the Association, in which he states that the Association is getting out some papers for subscription, to be used by committees calling on people personally. We deem best to ask for a payment of only 10 per cent. on account and then to call in the remainder of the subscriptions in installments as the money is needed. The Executive Committee of the Association is: Dr. William Taussig, Prof. C. M. Woodward, Col. Meier, Mr. E. S. Rowse, Rudolph Schmitz and E. L. Corthell. I would like to have the Secretary read the circular, as it gives in a few words the special reasons for the inception of this Association and the objects which it has in view. In reference to subscriptions to this monument fund, the total amount of which, as you will see, is $20,000, they can be sent directly to the Treasurer, Mr. E. S. Rowse, St. Louis.

Mr. Geo. S. Morison suggested that a subscription paper be handed round, which was done, and some $170 was at once subscribed.

CIRCULAR—EADS' MONUMENT ASSOCIATION.

DEAR SIR.—On behalf of the members of this Association, the undersigned take the liberty of addressing you and bespeaking your aid and material assistance in enabling them to carry out its great object.

The movement to erect a monument to JAMES B. EADS, commemorative and expressive of the gratitude and admiration which St. Louis, the country and the engineering profession all over the world, feel for this great man and his great works, arose in the hearts of many of our prominent citizens immediately upon the announcement of his death. It received its first impetus from the St. Louis Engineers Club, and resulted later in the organization of this Association. The mere announcement of the fact brought from other Engineering Societies, in the United States, in England and in France, spontaneous responses and requests to be allowed to contribute; and even in Mexico high officials of the Government have taken an earnest interest in the matter.

Surely, no name can be found fitter to be carved in enduring marble, nor features more deserving of the sculptor's chisel than those of this man, whose works are recognized by the civilized world as among the greatest achievements of our century His armored gunboats, during the war, shattered the blockade of our great river. His bridge first spanned it at its swiftest reach, teaching the whole world the secrets of deep foundations and long spans. His jetties opened its commerce to the fleets of Europe. His fiery eloquence and persistence, founded on

deep conviction, committed our nation to "one of the most comprehensive plans of river improvement ever conceived in the civilized world," and he finally fell a martyr to his profession, his dying energies devoted to the great project of extending the commerce of the Mississippi Valley directly into the Pacific Ocean.

We present for your perusal and consideration a copy of Mr. Corthell's eloquent address, from which we quote:

> "A monument befitting this grand figure of the age—this
> "world-renowned Civil Engineer—should be erected
> "overlooking the great river, whose commerce was so
> "dear to him, and for whose countless people he spent
> "his energies and laid down his life."

The citizens of St Louis will esteem it an honor and a privilege to furnish the site, and largely contribute to the cost of the monument. But so many expressions of approval of this movement have come to us from other cities in America and in Europe, that we deem it but due to the many admirers of Capt. Eads, both in and out of the profession, to give them an opportunity to join with us in the work.

No less a sum than $20,000 should be raised for a befitting monument, and it is intended to name a committee from among the subscribers and members, to which designs are to be submitted for inspection. Subscriptions may be forwarded to either of the undersigned.

Hoping for your early favorable reply, we remain,

Very respectfully,

E. L. Corthell,	Wm. Taussig, President.
Calvin M. Woodward,	E. S. Rowse, Treasurer.
Rud. Schmitz,	E. D. Meier, Secretary.

Executive Committee.

President Cooley then called for the discussion of the question presented by Mr. Morgan at the last meeting of the Society.

Mr. R. P. Morgan opening the discussion said: Mr. President and members of the Western Society of Engineers, what I have done and said so far in this matter has brought to my mind something that the great poet said: "What's in a name? That which we call a rose, by any other name would smell as sweet." I am quite sure there were no Societies of Civil Engineers at that time, or Shakespeare would have named them. Perhaps there are gentlemen here to-night who have not received copies of what I stated at the last meeting; if there are any, perhaps it would be well to re-state what I did, as opening the subject before I offer the resolution. My purpose is entirely single in this matter, and I hope the discussion that may take place will be on that basis; I want nothing that is not for the best interest of this Society.

Mr. Morgan then read the paper read at the February meeting, and which was printed in the Proceedings of that meeting.

Continuing, Mr. Morgan said: Perhaps I will not say anything more, but offer the resolution. I may have a few words to say afterwards, and I hope the members of the Society will fully appreciate my sentiments in respect to this matter. It is only a desire to put the Society on a footing that will be to its best interest in respect to its name,—one that will last in perpetuity and be satisfactory, and that will be in harmony with the great societies—the names of the great societies of civil engineers throughout the world. With that preliminary statement I will make this formal proposition, which will be addressed, of course, to all members of the Society. "Mr. President, and Gentlemen of the Western Society of Engineers: In compliance with the notice I gave at the regular meeting of the Society in January and February, I respectfully offer the following for your consideration:

Resolved, That Section I of the Constitution of the Western Society of Engineers be amended, and read as follows:

Section I. The name of this Association shall be, "The Chicago Society of Civil Engineers."

Mr. President, I have not even taken the precaution of getting a friend to second my resolution, therefore I am at the mercy of the meeting.

Mr. E. L. Corthell seconded the resolution.

The President called for a full discussion and upon the Secretary to read Article 6 of the Constitution.

MR. H. L. BRIDGMAN:—Mr. President, I desire to say a few words on that subject. Mr. Morgan's idea of attaching to it the name of Chicago, is, in my opinion, immaterial; but about the adjective civil, we are undoubtedly civil. It is also true that all engineers are either civil or military, but there are branches in the civil engineering profession all through the American States, and of those branches certainly one or two are nearly equal in importance, for instance, the mechanical and the mining engineers, and it seems to me proper, with all due deference to a proper esprit de corps, which these gentlemen no doubt feel, not to lump them in with everybody into the same basket. The fact that we are constantly confused with our workmen who drive engines is an unfortunate state of affairs, but we have to accept that, and I would suggest that we overcome that by calling ourselves an Institute; certainly the engine drivers have no Institute, and we might call our Society an Institute of Engineers.

MR. ISHAM RANDOLPH:—I wish to make a few impromptu remarks which I have prepared:

I hold in my hand a paper which forms a link between the quick and the dead. The fame of the dead has filled the world; the mighty works of his creation span rivers, open the gates of our land locked lakes and streams to the commerce of the world and, though the hulks of the fleet he built may be rotting in bayous fed from the mighty store of the father of waters, and the engines which made them very Goliaths for strength, among the thronging water craft, may have gone along with the boilers which fed them steam, to the scrap heap, and thence in company with the armor, mighty to withstand cyclones of hostile shot and shell which fell upon them in their terrific voyage from Cairo to New Orleans, to the furnace and the rolling mill, to appear recreated for the manifold uses of a peaceful civilization; yet the history of that achievement of this wonderful dead man belongs to the proudest records of our common country. So much for the dead. Of the living it may be said that he was worthy to be the trusted co-laborer of the dead, that he too is known to fame, that, honors from foreign lands and substantial rewards from many countries have been meted out to him for his labors as an engineer. This paper bears upon its title page the simple legend, "Remarks of E. L. Corthell, Member Western Society of Engineers, at a meeting of the Society, June 4, 1890, on a resolution to co-operate in erecting a monument to the late James B. Eads." This has gone out to the world, and let us imagine, has fallen into the hands of some who are not so posted as to the local headquarters of American organizations as to be able to spot them on a map of the Western Hemisphere. Such an one gets hold of this paper, he is struck with its evident claims to consideration on account of the man and the deeds which it commemorates; and the style and manner of the commemoration bespeak a high thought for the author. But, though Eads be assigned at once his niche in the temple of fame and Corthell be recognized as one of the living energies of the engineering world and the Western Society of Engineers may justly be supposed to be an august, active and learned body, yet the wonder creeps into the mind of the reader, where in all the lands which catch the rays of the setting sun does this company of the world's workers gather to hear addresses from its Corthells and its other mighty delvers in the fields of science, abstract and constructive. True enough such an one if he have an earnest desire to run this Society to earth, and has patience to wait for the transmission of question and answer through the mails, can find out that we are domesticated in the second greatest city of the western world, Chicago. But to accomplish even this he must know of some outside source of information to which he could turn to ascertain which of the Americas he should begin his enquiries in; or if, indeed, he should not overshoot the continent and try amid the Islands of the Pacific to corral this widespread and indefinite organization. He would not know by intuition that Chicago is the center, the essence of all things western. He could not without coming within its influence comprehend how she gathers to herself all the best things west of the Alleghanies and east of the Pacific; that from the frozen waters of the north to the ever tepid waves of the great gulf she gathers in the things that make the wealth of nations; and hence he would not address Mr. Postmaster, Chicago, to find out if we were at home. I have taken this

pamphlet only to illustrate a fact which is patent to us all; Western in our title does not inform anybody where we can be found. But indefinite, all embracing and illusive as Western *is*, standing to the fore of our name, it is not so bad as the rest of it. Society is all right, society is a power in the land: who, what self-respecting man or woman does not covet the entree of society in its best significance? So we will express our entire satisfaction with society as, and where, it is and will lift up no club before your mental vision to be feared or scouted. What we want is the proper prefix to engineers. In this broad land, where, as the darkie said, "everybody call heself to suit heself," names are often robbed of their significance, and this may be more truly said of engineer than of any other name with which I am familiar. As case in point a relative of my wife's when she heard of her having engaged herself to me, wrote to her sister in St. Louis telling her what had come to pass and mentioning that I was an engineer. Well, in reply the old lady wrote that she was glad to hear that the man of her young relative's choice was of steady habits, and she hoped that the union might prove a happy one, but she did think that she might have aspired to a more distinguished match. Now, the idea this old lady had of an engineer, doubtless, clothed him in blue jeans and overalls and jacket, streaked his face with smoke and gave him hands besmeared with oil and coal dust; nor do I feel degraded by being classed with such, for in the vicissitudes of life I have consorted much with these men and find that many a brave, true heart, full of generous impulses and right motives beats beneath those same blue jeans jackets, and I recognize as a truth worthy of the poets proclamation, "honor and fame from no condition rise, do well your part, there all the honor lies." But in the world's estimation distinctions exist and before that tribunal the civil engineer stands upon a higher plane than the engine driver; but in our confusion of tongues both are spoken of as engineers. Nor does it end there; the man who stokes and oils and cares for the engine of a threshing machine or of a saw mill is in common parlance an engineer. Here is a notice which appeared in the *Railway Age* a few weeks since: "Michael Mulconnery who has been an engineer on the St. Louis, Alton & Terre Haute road for thirty-one years, has resigned."

Who, from this notice, apart from the suspicious intimation of the name, can say whether this time tried veteran located the line, made the estimates, prepared the plans, let the contracts and brought to a successful issue the construction of this road, and has ever since watched over its maintenance and betterment, or whether he handled the lever of the 101 or presided over the measured strokes of Worthington or a Knowles pump, as it forced the steam-making fluid into some hospitable tank. Most, if not all of us know how our comrade, G. A. M. Liljencrantz, a man learned in the wisdom of Sweden's greatest schools, accomplished in the arts and sciences, a trained mind reinforced by a ripe experience, the trusted lieutenant of every colonel, major or captain of U. S engineers, who has held command of this engineering district for lo, these twenty years. Well, in the vicissitudes of the service this accomplished man had to use for a time a steam launch. This steam launch had to have a man in charge who understood it, and this man went upon the pay rolls of the United States Engineer Corps as engineer, while our friend went down upon the same rolls as assistant engineer. Had he been a vain fellow I doubt whether the fact of the column of figures showing perhaps four times the amount opposite his name as came in line with the engineer's would have compensated him for the looks of the thing. My friends, let us make a stand for our civility. Give us our proper prefix and let us have done with a position and a name so anomalous as our present one.

MR. CORTHELL:—I am not prepared to discuss this important subject, but just as I was coming in I met a gentleman who was intending to discuss it, and had prepared himself by considerable thought and research to do so; he was suddenly called out of the city, and he wished me to present a thought or two, which I do on his behalf entirely. He has examined our catalogue to ascertain the percentage of membership in Chicago, in a district outside of Chicago that can be reached by a 12-hours' railroad ride, and the percentage outside of that in the United States at large. He states that the percentage of membership in Chicago is 66, in the outlying district 25 per cent and outside of that in the United States, 9 per cent. The gentleman is Mr. Wallace. He wished me to say that he is heartily in accord with

this proposition,—would like to support it to-night, except that he is called away.

MR. L. P. MOREHOUSE:—I think I would rather listen to what others may say than to say anything myself on this subject. It certainly is a very important one. For my own part I have no feeling in the matter one way or other. I shall acquiesce willingly in whatever course the Society may take, because, for one reason, I do not consider that a name makes any particular difference in connection with this or any other organization, or with any individual. It may be proper for me as one of the oldest members of the Society, to say something with regard to the past, and perhaps the first thing to say, which some of you may not know—some of the younger members—that in 1869 this society was organized as the Civil Engineers' Club of the Northwest, rather a pretentious title, and one which to some of the members at that time was not entirely satisfactory, but still the name was adopted, and the idea was to make it an engineer's society that should embrace the engineers of the Northwest, and under that name the Society prospered fairly for a number of years, when, in the wisdom of some of the most influential members it was thought best to change the name, and after a great deal of thought given to the matter, and very careful consideration of it in all its aspects, the present name was adopted,—the Western Society of Engineers. Every portion of that name was carefully considered at the time; the same objections which have been made to-night to the use of the word "Western" were brought up then, the same objections to the use of the word "Engineers," and the members then in their wisdom decided that the "Western Society of Engineers" was the title proper for this Society; that it would endeavor to be a national society; the intention was that it should not be a local society; there was an ambitious idea—not shared by all members, but by those who ruled at that time, and I think they were a minority, still they carried that point—there was an idea that the Western Society of Engineers would rival the American Society of Engineers, and that Chicago should take the same place as the headquarters of the Western Society of Engineers which New York occupies as the headquarters of the American Society. I suppose that at the present time that feeling does not prevail in the Society, and there may be a reason for changing the name to the Chicago Society which did not exist at the time when the present name was adopted. Our societies have all of them become local societies. I suppose I can say with considerable truth with regard to the American Society, that it is not at this time distinctively *the* American Society of Civil Engineers; the same reasoning which would induce us to change our name from the Western Society of Engineers to the Chicago Society would apply to the American Society. That society might with about as much propriety change its name to the New York Society. It has a larger proportion of members scattered through the country, of course, than the Western Society has, but yet I think it is generally acknowledged that it is almost practically a local society like our own; therefore, I do not see any particular force in the reasoning which says, because we are located in Chicago and that Chicago is the center of our effort, therefore we should take the name of Chicago Society. As I say, I think it would apply just as well to the American Society. But I am free to say this, that as a name, I think the Chicago Society would be preferable. It is simply, it seems to me, a question of policy, a question of wisdom, whether at this time it is worth while to erase the name under which this Society has been operating for a number of years past, to sink into oblivion the Western Society of Engineers and all pertaining to it, and organize practically a new society called the Chicago Society. As a member of the Western Society of Engineers as one of the original members and a present member, it does not seem to me desirable to make that change simply that we may have a name that will be strictly more accurate in designing the locality of the Society than the present name. I do not attach much importance to names, but it seems to me that the principle is a good one not to meddle with names after they have been adopted; when a boy has been called John, even though when he becomes grown he may think that George, Arthur, Adolphus or Leander would be a better name, that it is hardly worth while to go to the Legislature, or any competent source, to get the name changed, because when you adopt that principle of action, it seems to me that you are at sea. You have nothing fixed, and if it is desirable to change your name to-day, why

next year, or next ten years, it may be desirable to change it again. Permanence, it seems to me, is more desirable that the exact meaning of the words which are used. As to changing the name of Engineer to Civil Engineer, as I have said, that matter was very carefully considered when the present name was adopted. There are strong reasons on both sides of the question. As I said, I have no feeling myself, but it seems to me there is no objection to the word Engineer, for the reason that it has been abused and is continually abused. We find the same thing with regard to the word gentleman: every man is a gentleman, whether he deserves the title or not. Almost every man is a Professor, whether he aspires to the title and deserves it or not. Mr. Sullivan, of Boston, is called a professor, I believe. There are professors in the art of shoeblacking, whitewashing, and the like of that, still we do not drop the word professor entirely for the reason that it is often abused. It seems to me the word Engineer is certainly a very proper title, and if people do not know what it means, there are enough to find out what this Society does, what its object is. There is no danger of its being confused with any society of locomotive engineers or stationary engineers, or the like of that. Those are my views, gentlemen, upon this subject, and they amount, I suppose, practically to this, that in my own mind there does not seem to be a reason for the change, but should the majority of the society, or two-thirds of the society decide to make the change, there will be no repining on my part. I certainly shall acquiesce very cheerfully; I shall not oppose the change, but shall be willing to abide by what seems to be in the wisdom of the Society, the better course for it.

MR. F. S. WASHBURN:—Mr. President, it seems to me that we are either adopting a very Chicagoan spirit or a very un-Chicagoan spirit. It seems to me that we include not only the State of Illinois, but parts anyway from the rest of the country. If we do not think that ourselves, we are rather contracting than expanding. We believe, and I think it is a general belief, that Chicago is not only to be the greatest city in numbers, but some day is to be the financial center of this country. To call the American Society the New York Society, seems inconsistent. To call an association of engineers which is to be the largest in the United States by the name of Chicago, seems to me doubly inconsistent. In regard to the word "Western"—Chicago may be in the East—the word Western would not convey the meaning; I do not think it necessary. The word Western, in its most comprehensive meaning, might apply to the whole Western Hemisphere, and it occurs to me now that possibly that name is more descriptive than any other that could be found. The name certainly, for the next two years, will be more prominent before foreign people than it ever has been before. As to the matter of changing the name to Civil Engineers, I think that the word Engineers is confining it wholly to civil engineers. The fact that we may be misunderstood, as we may, for an association of locomotive drivers, operators of pumps, etc., while it may hurt our pride a little, it seems to me is unimportant. Those people who want to know us will never confound us with anything but engineers as distinguished from military engineers. It seems to me, in a few words, that the present name of the Society is just as good a one as we can adopt. Anything may come up in the future—we are developing very rapidly—I can remember when we had fewer numbers than we had in our American Society by far, and to-day I think there are more; I think the average attendance of our Society is greater than the American Society.

MR E. PHILBRICK:—Though I am not one of the older members, and do not know the reason why, I am in favor of a change. When I went to college, I went to a school which was called the Illinois Industrial University. I suppose you all know what the term Industrial School usually implies,—they are understood to be a reform school. I was in favor of changing the name of the school, calling it something that would be more appropriate. I had committed no offense for which I should have been sent to an industrial school, and the agitation of the citizens caused in regard to changing the name resulted in changing it to the University of Illinois, which I think is more appropriate. If the name of the Society does not express the true meaning of the Society, I think it would be desirable to have a name that would express it. In speaking of the Western Society of Engineers, the people throughout Europe, and a great many through the Eastern part of Illinois, look upon the West as yet in a savage state, and they may think that perhaps the engineers are in

a similar state. In regard to the word civil engineer, I think the word civil, so far as the word engineer is concerned, is as broad as the word engineer; I cannot see why a civil engineer cannot be a mining, or bridge, or railroad engineer, or an architect, or any other branch of engineering but I do not think the Western Society of Engineers would admit an engine driver, or a man who runs a pump.

The President here asked Mr. Morgan whether he wished to press the discussion to a vote this evening, as there was a valuable paper to be read, and it might be well to postpone the subject now in hand.

In reply, Mr. Morgan said: I have no desire, whatever, to press the matter to a conclusion, but very much prefer that time should be taken to consider this question, because we want to decide it properly, and if there are any here whose minds are not made up on the subject, it seems to me it would be better to take more time and let it be considered. If it is right to do it, why let us do it, if not, let us avoid doing wrong. That is my feeling about it. I have no desire to press the matter to a vote hurriedly, and if there are any other discussions before the Society, I am entirely willing to put it over. I do not see that there is any reason for hurry, but on the contrary, I do see reason why every member of this Society should have an opportunity to hear and thoroughly consider the subject that we have under discussion. Whichever way the decision would be, perhaps it would be better to have time taken. As I stated before, I only have the single purpose. I have listened with great interest to Mr. Morehouse, I have known him for a great many years, and I know more of him than he perhaps supposes. I only have one point to make in regard to Mr. Morehouse's remarks. As I remember his remarks he said that the American Society of Engineers might as well be changed to the New York Society, as to change the Western Society to Chicago. The difference between the two must be apparent to every one. The American Society took possession of all of our territory, and Western Society took possession of none, it made an imaginary line.

Mr. Morehouse:—I would like to ask a question to see if I understand the status of this matter exactly; as I understand it, it is this: Mr. Morgan has offered a resolution proposing an amendment to the constitution. That has been seconded. We are simply discussing the matter up to this point. upon which we will take a vote, either this evening or some other time, of the members present. If two-thirds of the members present vote to second Mr. Morgan's resolution, then it goes before the Society; all that we are discussing now is whether two-thirds of us will second Mr. Morgan's resolution or not?

President Cooley:—That is the proposition. And whether this should lie over a month or two.

Mr. Morgan:—I do not make the proposition myself, I merely suggest that, and I think, by the spirit of fairness which is manifested here to-night, I thought it would be in the common interest of the Society that the discussion should be printed and sent out to the members, so that they may understand. I think every member is entitled to that, although under strict rulings that would not be so. Under any circumstances I would be willing to adopt your suggestion, because in anything that is good, there is nothing lost by time. While it has been a personal matter so far, I can appreciate that it might take a different form, and that there may be a committee appointed, and that it will take a different form, and finally be acted upon by the Society, but to do it, it was necessary to bring it in some form, and I have done this to the best of my ability. and I supposed it would take some other form very likely.

President Cooley:—I make this suggestion, that the further consideration of this question be postponed until next meeting.

Mr. Morgan:—The reason I suggested it 60 days from now was, that perhaps at the next meeting we might not have returned from New York,—the committee might not be back, and I would like to be present when the matter is taken up. That would be the May meeting. Is it necessary to make a motion for the consideration to be postponed until the May meeting?

Mr. M. E. Schmidt:—I would suggest to refer this question to a committee of five, to be reported sixty days from now. Seconded.

Mr. Morgan:—I do not understand that that would be in order because the

discussion was not complete, and to move that it be placed in the hands of a committee before the discussion is completed, would, of course, be taking a different course in the matter than that suggested by the chair and what has been generally accepted; the idea is that it is an adjourned meeting till the May meeting.

MR. SCHMIDT:—It would bring additional information if a committee would consider this question in the meantime, and I do not think it would be necessary to take any action in it; it would simply leave five members occupied with this subject, appointed to present their views to the Society 60 days from now.

MR. WM. E. WILLIAMS:—It seems to me that in making this choice of names, a conclusion that would be arrived at by a committee would not affect this matter; it is a matter of each member's individual choice; it is merely a question whether a majority of us want to retain the name of Western Society of Engineers, or if more of us want it changed; that is about all there is to it. I do not think there is anything more to do than to find out what each member's individual opinion is, and it seems to me that this discussion that is going on to-night is about the best way for arriving at that; it is a committee of the whole membership that is present, and if there is not time enough to give every man a chance to air his views to-night, we ought to postpone this to some future day, and so notify each member that he may be loaded for the occasion.

It was finally voted to postpone the further discussion of the subject until the May meeting.

Mr. M. E. Schmidt then presented the following resolution in reference to the action the Society might wish to take in regard to the communication of the Mexican Society. Mr. Schmidt said: I have been eight years amongst the Mexicans, and have had every courtesy shown me, and I think we should take some action to show that we appreciate their fraternal suggestions.

Resolved, That the proposition made by the President of the Mexican Society of Engineers and Architects to join us as a corresponding society, be cordially accepted.

This resolution was seconded and carried.

President Cooley then called upon Mr. T. T. Johnston and said: Mr. Johnston's paper is on the "Artesian Water Supply of Memphis." There are some novel features in connection with it which I think will interest most of the members.

A valuable and very interesting paper was then read by Mr. Johnston, which will be presented in full in an early issue of the JOURNAL.

MR. CORTHELL:—I would like to ask if this paper, which certainly is very important and very interesting, can be published with the plates; it ought certainly to be published in the ournal of the Association, where every one would have an opportunity of reading it carefully and filing it away. We do not get many of these papers with plates, in our Society, and I think it is about time we did.

PRESIDENT COOLEY:—If Mr. Johnston will furnish the plates, I have no doubt the paper will be published with them. Is there any member who would like to ask questions of Mr Johnston?

MR. BRIDGMAN:—I would like to know what method they would pursue in turning off the water in case of an extension of a tunnel.

MR. JOHNSTON:—There are quite a number of ways. The idea would be to sink a shaft near there, and going on and building our new tunnel and cut our wells out, and way down make our connection to these parts with the aid of divers; that is a kind of work that has been done successfully.

MR. BRIDGMAN:—Would it not shut off the entire supply?

MR. JOHNSTON:—No, they could go on pumping from these wells until the new ones are attached to the tunnel.

MR. BRIDGMAN:—Would it not be possible to plug each well if they wished to?

MR. OHNSTON:—Yes, in fact some of the wells have gotten out of order occasionally, and by replacing of the wooden stopper the strainer can be removed from the well, and almost any repairs made to it that is desired.

PRESIDENT COOLEY:—Gentlemen, is there any other business?

MR. MORGAN:—Before adjourning I would like to say a word. I have been very much interested indeed, and instructed, by the presentation Mr. Johnston has made of the Well Works of Memphis, and especially so as I had the pleasure of passing

through them before the water was admitted, and I believe that a paper of such merit and so carefully prepared, so interesting and instructive, ought to receive the recognition of a vote of thanks, and I propose a vote of thanks to Mr. Johnston for this evening's entertainment.

Seconded and carried.

Adjourned. JOHN W. WESTON, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

344TH MEETING, MARCH 18TH, 1891.—The club met at 8:15 p. m., in the club rooms. In the absence of the President and Vice-President, Mr. S. Bent Russell was elected chairman pro tem. Twenty-two members and two visitors were present. The minutes of the 343d meeting were read and approved. The executive committee reported the doings of its 106th meeting.

Mr. Guido Pantaleoni was elected a member.

Prof. Johnson reported for the portrait committee, that an oil portrait of Capt. Eads could be purchased for $50, and requested a vote of the club as to their wishes. By vote the committee was authorized to purchase the portrait.

By vote the executive committee were instructed to examine the question of more commodious quarters.

Prof. Johnson presented a proposition to increase the membership of the club. By vote this was referred to the executive committee for action.

The question of "Cable and Electric Railroads" was opened by Col. Meier. An animated discussion followed, which was participated in by Messrs. Holman, Kebby, Bryan, Nipher, Johnson and Moore.

For the next meeting a paper by Mr. John H. Curtis on "Notes on Railway Locations," was announced.

Adjourned. ARTHUR THACHER, Secretary.

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ROADS AND ROAD BUILDING.

By C. Frank Allen, Member of the Boston Society of Civil Engineers.

[Read November 19, 1890.]

It is useless to spend time in calling attention to the necessity for good roads, or to the fact that their importance is receiving a large share of attention at the immediate present. No one who faithfully reads the engineering periodicals can fail to be aware of the interest of engineers in the subject, or of the fact that legislative action has been demanded in more than one of the most prosperous and populous states of the Union.

There has been not a little known of the proper principles of road building for very many years past, and it is easy to say much that is not new on this subject. If the present paper fails to weary with what is old, and succeeds in provoking discussion and an interchange of views among the members, especially those who are actively engaged in road building at the present time, in that case the writer will have no cause to feel disappointed in the result.

Roads may well be discussed under the heads of

1. Location.
2. Form of cross-section.
3. Workmanship and materials.
4. Maintenance.
5. Legislation.

1. Location.

The engineering details of the location of a road need not here be recited. The principles differ not very much from those applying to railroads. In the case of railroads, there has been much attention devoted of late to the economic features of location, and for this purpose it is important that due attention should be paid to the elements of economy, which are:

(*a*.) Cost of construction.
(*b*.) Cost of maintenance.
(*c*.) Cost of operating.
(*d*.) Amount of revenue.

It is well understood that the railroad should be located so that the amount of revenue, less the sum of the cost of operating, cost of maintenance, and interest on cost of construction, shall be as large as possible, this being the profit. With common roads the owner of the road does not pay the operating expenses, and does not receive any revenue except in the case of a toll road. Nevertheless the public (which the town or city or county, the owner of the road, represents) pays for the cost of operating, and receives the benefit even if tolls are not levied, and therefore in the case of common roads, as well as in the case of railroads, modern engineering should require that in location due attention should be paid to the four items of cost of construction, cost of maintenance, cost of operating and amount of traffic (revenue being out of the question). It would be useless to attempt to formulate any rules in the matter as has been done with railroads, but it is evident that a more expensive road would be justifiable if the additional expense would decrease the annual cost of maintenance, or if it would allow a horse to draw a larger load, or if over it there would be carried a larger traffic. All that can be said from the economic side of location, is that the best engineering judgment we possess should be used in considering and giving due weight to the demands of the four items mentioned, in fixing the location. In this connection nearly all text-books prescribe that a road should generally run around a hill rather than over it, but it is almost as important for us to have in mind that a road partly over the hill with grades not excessive would be preferable to a road around the hill if the road over the hill was through gravel and high and dry, while the road around it was through mud and over ground low and not easily drained. The quality of material, in its effect in producing a good hard road surface, might be of more value, not only as to maintenance, but also for the requirements of operating or conducting traffic, than the low grades on a road generally or frequently in bad condition. In a similar way the opportunity to secure good gravel or broken stone close at hand might often determine the proper location.

In locating common roads it should also be borne in mind that unlike a locomotive, a horse in starting, or for a short time, is capable of exerting several times the force which he can exert on the average.

2. *Form of cross-section.*

For the total width of land secured for a road, it is well to be generous; for the width laid out for traffic no more than is necessary should be provided for. The amount of money unnecessarily expended in greater width could be better utilized by investing it in better material for surface, or in better drainage, or in surfacing a greater length of road. A width of sixteen feet is a common minimum. Text-books and engineers are pretty well united in the opinion that thorough drainage is an essential to good roads. Nevertheless side drains fill up with weeds, and, so far as the writer

knows, little or no attempt is made about here to use drain tiles to under drain low and wet spots in country roads. It has seemed to the writer that matters apparently trivial are often of importance, and that if engineers would, when opportunity offers, make improvements in a few bad spots by the simple and inexpensive expedient of under drainage, town authorities might become more readily educated to appreciate an engineer as a money saving institution, and it is important that engineers should strive to make a reputation as money savers rather than as money spenders altogether. The objects to be secured in the drainage of a road should be threefold, to:

1. Intercept water on its way to the road.
2. Remove promptly the water which falls on the road.
3. Carry away any water which finds its way under the road.

The second point brings us to the old disputed question as to the shape of the road-bed proper, whether an arc of a circle, an arc of an ellipse, or two straight slopes united by a short curve in the middle. To the writer it seems that if the object be as stated, to remove promptly the water which falls on the road, then the shape should be the one best adapted to that end: that is two straight slopes united at the middle of the road by as short a curve as will allow of satisfactory rolling. The fact that engineers and road foremen alike are not agreed upon this point, indicates possibly that the difference in form in ordinary widths of road is theoretical rather than very serious. What the rate of side slope shall be is a matter of importance. 1 in 24 or 1 in 30 has been common, but any uniform rule is not a good one. With superior smoothness and hardness of surface the side slope may be flatter than in the case of a rough and soft surface. Again with a steep grade (longitudinal) the side slope should be steeper than with a flat grade. This is necessary if the water is to be promptly removed to the side of the road. Otherwise it will tend to run down the full length of the road. A rule adopted for the streets of Providence is an illustration of what is desirable.

Grades.	Side inclination or cross slope.
For low grades up to 4′ per 100	0.03 to 0.04
from 4′ to 6′	0.05
6′ to 9′	0.08
9′ up	0.10

3. *Materials and Workmanship.*

In road building the question of side slopes of embankment and of excavation, and similar matters hardly warrant discussion here. It may be worth while, however, to refer briefly to methods of executing earthwork. For very short hauls it is believed that the ordinary "scraper" is the most economical. For longer hauls there are used very frequently one of the four following:

1. One horse carts.
2. Two horse carts.
3. Two horse wagons.
4. Wheel scrapers.

Of these, it is probable that the wheel scrapers will prove more economical for moderate hauls. They are claimed to be very severe on stock, however. As to the comparative economy of the other three, the writer would prefer to hear opinions from others rather than advance them himself. Which is used seems to depend largely upon the customs of the section of country in which the work is executed. The writer left the one horse cart in New England, followed the wagon through New Mexico to a point in Texas, where he found that his old friend the one horse cart had pushed its way from California in the hands of John Chinaman. A possible advantage in the "wagon" results from the fact that a bank made with wagons will probably be built up in layers from the bottom, rather than built out from the end of a dump, and may thus prove a better bank. There are many places, however, where the one horse cart can be used to great advantage, especially when from any cause there is little room to turn.

Many books or treatises on road building prescribe that the surface soil shall be stripped for a suitable foundation for a bank, but banks are often made without this precaution being taken. In such cases trouble is, especially likely to be experienced at the point where the road passes from cut to fill. It is essential that the soil should be stripped at this point, otherwise there is a soft place ready to soak up water and weaken the bank just below it.

The roadway proper may be considered to consist of two main parts—the foundation and the wearing surface. Very many, or in fact most of our roads, have no specially prepared foundation other than the base of the cut or the surface of the fill. In some a special or artificial foundation is laid, as in the Telford road.

The surface in general is either earth, gravel or broken stone, and whatever may be our opinion as to the merits of earth roads, there can be little doubt that a majority of the roads in this country are earth roads, and are likely so to continue for many years. It seems to the writer the part of wisdom that we should make an earnest effort to have the earth roads as good as possible, and for this purpose we must attend to the drainage and give the surface the proper shape, and perhaps roll them as soon as the surface is in proper shape. The writer is in doubt as to how much value there may be in rolling earth roads. Does it pay for the expense? Would it be better in ordinary cases to spend the same amount of money in graveling a portion of the road rather than roll the whole of it? The answers to these questions will perhaps depend much in the quality of the earth. In some parts of the country the natural surface soil makes good roads; in others nothing short of an artificial surface nearly water-proof will be of much value. If any members have had experience in rolling earth roads, the experience thus gained would, it seems, be of value to many of us. In the improvement of the surface everyone has perhaps become familiar with the prescription for adding gravel to a clayey road, and clay to a sandy road. Few perhaps have heard of the expedient, tried occasionally in the West, of improving a sandy road by spreading a layer of straw upon it. At a convention of

Engineers and Surveyors of Indiana, a member stated that four inches of loose straw spread on a sandy road will in a few days travel grind into the sand and become as firm and hard as a dry clay road. Without personal experience or observation in the matter, the writer has information which he considers reliable to the effect that good results do immediately follow, but are not permanent. The device in any case seems not well suited to this section of country, on the score of economy.

Gravel Roads.

When something better than an ordinary earth road is desired, the next step in general is a gravel road, and gravel roads exist in great abundance throughout the villages and towns of Massachusetts, and are largely used even in the minor streets of many cities. The gravel should not be a dry, clean gravel, but should have sufficient clayey or earthy matter to give it the binding quality. Any pebbles greater than 1½″ in diameter should be screened out, and with some gravel it may pay to also screen out a portion of the fine material.

Perhaps the best way to build a gravel road is to lay down a layer of gravel 4″ thick, and roll it thoroughly with a roller weighing 1½ to 2 tons (2½′ to 3′ in diam. 5′ to 6′ long); for the bottom layer a light roller is the proper thing, as a heavy roller will compress so closely that the two layers will not sufficiently bind together. The gravel should be kept well sprinkled and damp during rolling. When the bottom layer has been well rolled, the second layer is added and treated in the same fashion. Finally the top layer is added and thoroughly compacted by a heavier roller, say 5 tons or heavier. The sides of the road should first be rolled compactly, and then the middle: in this way the middle, which receives most of the wear, has the compacted sides to resist the spreading of the material, and can thus be rolled very hard and solid. A gravel road well constructed will have a substantially impervious covering, and will shed the water to the side ditches. If the side ditches properly do the work of under drainage, such a road should do excellent service without being unduly expensive.

A more expensive gravel road may be built upon what is substantially a Telford foundation. E. P. North mentions such a road as is in use in the New York Central Park. It is not, however, a common construction. When the simple gravel covering is not sufficient, the ordinary custom is to use broken stone for the surface.

An excellent alternative for gravel exists in furnace cinders. Railroad companies are much in the habit of covering their railroad yards with furnace cinders or engine cinders, which compact and make an excellent surface. While railroad companies would not often part with their own product of cinders, there are many cases in which a supply could be secured at little or no cost from manufacturing establishments. Especially with a clayey road they work in and make a superior surface.

Another expedient was used by an Indiana engineer in a place where gravel was not readily procured, in the shape of coal slack. This was used for the under two-thirds of the covering, gravel of some sort being

secured at considerable cost for the upper third. A portion of road constructed in this way is said to have given better results than adjoining portions built of gravel exclusively. It was not stated whether the two portions were of equal thickness. The slack in many parts of that state and other western states can be obtained for nothing or at nominal cost, is light in proportion to its bulk, and can be hauled comparatively cheaply in consequence.

Shell roads have also proved very satisfactory in many places where shells could be readily obtained in sufficient quantity, and sandy roads were the alternative. Anyone who has ever threaded his way by wagon from Siasconset to "Town" on the Island of Nantucket, has had a chance to appreciate the advantages of the shell road that succeeds the sandy tracks in which the wheels sink nearly to their hubs.

Broken Stone Roads.

An improvement on the gravel surface is the broken stone surface when properly made. The use of a broken stone surface does not, however, by any means assure a good road. There are very many points to be observed in order to secure the best results. In the first place as to the quality of the material used. Good road material should be hard, tough, not affected by the weather, and must bind together well. By tough is meant the reverse of brittle. It must be hard to resist wear; it must be tough to resist splitting under traffic, and must not be disintegrated or weakened by wet or frost or by the elements in any way. Furthermore, the material resulting from wear should be of such quality as to bind or cement the angular fragments together. It is somewhat difficult to find stones that unite all the qualifications. The binding property is certainly an important one.

The materials used must, of course, be obtained close at hand, as a rule, owing to the heavy cost of haulage, and we must in general be content to use the best material we have. No preliminary test of the qualities required can be made which will give fully correct results. Only trial and actual wear in the road is conclusive. However, it is well to put your best foot forward in making a selection for experiment or trial, and the following procedure, recommended by an excellent English authority, will be useful in this connection:

1. Ascertain from local persons, such as masons, quarrymen and others, their opinions as to the qualities of the stones in the neighborhood.

2. Make a trial for toughness. Set a good stone breaker at work upon a heap of stone, and see how much he will break in an hour.

3. Find the power to resist wear. French engineers put the broken stone into a revolving cylinder, and note by weight what the stones lose by contact. Another method used is to press the stone against a grindstone with a known pressure, and observe the loss of weight.

4. The compressive resistance may be measured in a suitable testing machine.

5. The effect of weather can less readily be ascertained with great certainty. The following test has been advised for this purpose: Soak the

stone in a saturated solution of sulphate of soda; on exposure to the air a poor stone will disintegrate. The value of this test may be considered doubtful, as with some it has failed to give results of any value for road purposes. Actual freezing in an ice machine would doubtless prove a more valuable test.

In addition to the natural stones suitable for road metal, it should be mentioned that slag from smelters or furnaces, is a suitable material, and could in many cases be used to advantage. Stones of different quality should not be mixed in the same layer of road metal, more particularly in the surface layer which takes the wear. If the wearing surface be not of uniform quality the softer parts will wear away, the harder parts work loose, and the final result will prove inferior to what would be secured if the softer material alone were used. There is perhaps no serious disadvantage in using a softer material in the bottom layers, if this be securely covered by a harder layer of uniform quality.

In breaking the stone, although stone *cracked* by hand is doubtless superior to stone *crushed* by machine, yet the cheapness of the latter will in general dictate the use of crushed stone even if the edges are somewhat injured and the stone weakened in the crushing. It would appear to be generally recognized that the stones should be of uniform size throughout each layer, and as nearly cubical as may be. Macadam used stones of uniform size from top to bottom of the road covering, and claimed better results with stones as small as 1½″, or rather 6 ounces, for he preferred to gauge by weight, although he once prescribed "such a size as the stonebreaker could put in his mouth," a method of gauging clearly not adapted to this country, where the sons of Italy, Ireland and Africa compete for employment.

As to the size, Codrington, in his excellent book (an English work) on "The Maintenance of Macadamized Roads," says "the tougher the stone is, the smaller it may be broken with advantage to the road, but of course at an increase of cost. On roads where the traffic is of a heavy character, breaking the materials to a small size is an expense not attended by any advantage, and if the stone is not very tough, too large a proportion of small stuff is produced which is of little use in the road, and can only be separated by screening at an extra expense. Metalling to be laid with a roller need not be broken so small as it must otherwise be. When stones are once well bound together, as they are by a roller, they are the stronger for being larger."

Then the road metal should be rolled, and binding material should be added previous to the final rolling. Road-rollers are a modern itstitution their use in England dating from about 1840, while steam rollers came into use somewhat later than 1860. Macadam therefore compacted by traffic as a matter of necessity, and he also insisted strenuously that no binding material should be added. It is possible that for traffic compacted roads better results were reached without using binding material, although Telford, who was contemporary with Macadam, allowed its use.

Of the comparative merits of (1) traffic, (2) horse rolling, (3) steam

rolling, there can be little doubt as to the superiority of steam rolling.

There are many objections to compacting by traffic:—

1. It is cruel to horses to pull a load where the foothold is loose angular stones.

2. It is an impediment to traffic until compacted. Far less than a full load can be hauled through loose broken stone, and a turnpike road under ordinary traffic will require perhaps three months to compact it.

3. It results in a large amount of unneccessary wear to the wheels of vehicles.

4. It is wasteful of the broken stone. Examinations made in England by Thomas Codrington go to show that in the structure of the best roads, $1/5$ to $1/4$ of the whole coating consists of a fine, muddy, cementing matter, and probably $1/3$ is of small size, such as would be removed as ordinary scrapings. It evidently is not economy to pay a high price for broken stone and then grind off one-third of it by traffic, when good binding material may be secured at a much lower price. This objection applies properly to Macadam road, not to Telford.

5. It involves a considerable expense for labor in raking stones into the ruts during the compacting process.

6. Much dirt and unsuitable material (horse dung for instance) is incoporated with the road metal.

7. In cases where a thick coating of metal is not necessary for traffic, a thinner layer of road metal can be successfully rolled than can be compacted by traffic.

8. The stones, angular at first, have become more or less rounded by rubbing against each other, and have thus been injured for road purposes. Examinations of road metal in old roads have shown the stones to be more rounded when compacted by traffic (as would be of course expected).

9. Finally, it has been found by experiment that traffic compacted roads are inferior to rolled roads. Then as regards horse rollers and steam rollers, it has been found that the weight of horse rollers is limited. A roller of six tons would require six horses to pull it, and six horses are rather unmanageable in an ordinary road. They cannot be turned easily, while the horses feet tear up the road and to some extent undo the work of the roller.

An experiment indicating the comparative effect of steam rolling, horse rolling and traffic, is given by Mr. North as follows (p. 111, Am. Soc. C, E., 1879): "Some refuse Westchester marble, a very soft rock, was delivered on some of the roads at about 25 cents per cu. yd., and hand broken in place at the rate of about one cu. yd. per hour. A portion was rolled before any traffic went over it, some after about two weeks of traffic, and some after six weeks; of the rest part was horse rolled and part compacted by wheels, the quality of the stone, traffic, etc., were very nearly the same; that not rolled by the steam roller soon wore into holes, the first mentioned is, after standing two winters, in very fair surface, the others decreasing in the order in which they are mentioned. The difference is so noticeable that any one could pick out their sequence as mentioned."

The experience of Mr. North was to the effect that the heavier the roller the better the road, and the roads receiving the most rolling proved the best wearing roads. Present practice it is believed is in harmony with the results of these experiments and the conclusions stated.

As to the use of binding material, road builders have been for many years familiar with the unsuccessful attempt made in Central Park to roll a road by steam roller without binding material, and the desirability or necessity of binding material is almost universally recognized. Deacon, a leading English authority, says in a paper the "Proceeding of the Institution of Civil Engineers" (Deacon, Proc. Inst. C. E., 1879, p. 19.):

"Much difference of opinion exists as to the best method of finishing or blinding the surface. The author has tried many methods. Under a 15 ton steam roller, preceded by a watering cart, 1.200 yards of trap rock macadam, without blinding, can only be moderately consolidated by 27 hours continuous rolling. If blinded with hard rock chippings from a stone breaker, the same area may be moderately consolidated by the same roller in 18 hours. If blinded with siliceous gravel from ¾ inch to the size of a pins head, mixed with about one-fourth part of Macadam sweepings obtained in wet weather, the area may be thoroughly consolidated in nine hours. Macadam laid according to the last method wears better than that laid by the second, and that laid by the second much better than that by the first." The use of street sweepings as binding material is perhaps not very common in this country. So far as the sweepings are the product of the wear of road metal having the proper binding quality, they can be expected to be valuable.

What the binding material should be is less certain. Although in the practice of many engineers, the screenings from the stone crusher are considered almost indispensable, others even prefer a clean, coarse sand, or fine gravel. It is doubtful whether, as a rule, there can be obtained from a crusher a sufficient quantity of screenings to serve as a binding material for the stone broken. It would seem probable that screenings from stone of the proper binding quality might prove superior to sand or gravel.

The road metal should be rolled with a light roller before the binding material is added. If the road metal is applied in several layers, each of the lower layers should receive a rolling with a roller heavy enough to compact it, and yet allow the succeeding layer to properly bind in with it. The heavy roller should then be used just before applying the layer of binding material and again after this, keeping the material wet enough to secure the best results.

Finally, shall the road metal be applied directly above the prepared surface of the roadway, or shall it be laid upon a Telford foundation? The answer to this question, it seems to the writer, should be this: the road metal covering is used to serve two purposes; first, as a wearing surface; and second, as a protecting covering to shed water. If this be the proper way to regard it, then the road metal covering should have a suitable foundation; and this brings us to the question of what is a suitable foundation. The walls of a house may be founded upon

piles or upon concrete, or laid simply upon the natural soil suitaby prepared. In other words, the foundation used is what is found necessary to meet the requirements of each special case, this depending upon the weight to be carried and the material of the soil. In an entirely similar way the foundation of the road metal covering should depend upon the character of the traffic, and the quality of the soil. Where the traffic is not very heavy, and the natural soil would be almost, or quite hard enough to carry this traffic if it were possible to keep it dry and in good condition, in such case a covering of four inches of road metal, the Bridgeport construction, ought to be sufficient. In some cases, a thicker layer will give additional strength and serve to distribute the load over a larger area of foundation, and thus give good results. In other cases, especially with heavier traffic, a Telford foundation of stones set on edge will often be desirable. In cases of especial difficulty a concrete foundation will prove of value; I know of no cases of this construction in the United States, but in Great Britain such construction was used by McNeill with apparently the sanction of Telford, as well as by others. The cases were it was desirable to adopt this construction would probably not be many. The ordinary practice in this neighborhood is to use for heavy traffic a Telford foundation; for light traffic 10″ or 12″ of road metal without Telford foundation. In many cases less thickness of road metal would no doubt serve. The additional thickness, of course, does no harm, but the money required might sometimes be better invested in a thinner covering of an additional quantity of dirt road.

The foundation of rubble stone, or stone laid flat rather than on edge, is familiar to some of the members, but is not favorably regarded by those road builders whose opinions are most highly valued.

When road metal is laid directly upon the natural soil, it is essential that no clay, or mud, or other similar material should be all wed to work up into the road metal to act as a lubricant between the stones. In many cases a thin layer of sand or fine gravel under the broken stone, will effectually prevent any difficulty of this sort.

It should be borne in mind that for roads of broken stone, as well as for roads of earth or gravel, the soil should be well under-drained, if necessary, so that the road covering, either with or without the Telford foundation, should rest upon earth which is as dry and solid as circumstances will permit. The writer is strongly of the opinion that outside of the larger cities, the under-drainage of roads has in this country failed to receive the attention it deserves.

There remains the subject of maintenance, but as there has necessarily been consumed more time than has seemed desirable in a paper intended mainly to provoke discussion, in considering the location and construction of roads, the writer, in harmony with the example of many eminent engineers, having brought his construction to completion, willingly leaves to his successors the difficult, but it is hoped not impossible, task of attending to the maintenance of the roads whose construction he has described.

Road legislation, too, offers an interesting field for consideration, and the writer had hoped to give the subject some attention in this paper, but

found that neither the time at his disposal not the time available for this paper at the meeting would allow of it.

The opinion is, however, ventured that here, as in many reforms, as much is to be hoped for from general agitation and enlightenment of the people, as in the direct results of legislation. It is no doubt true, however, that the passage of any legislative act of importance has a tendency to call public attention strongly to the matter, and often accomplishes indirectly more good than results directly from its passage and enforcement.

DISCUSSION.

Mr. SIDNEY SMITH:—I should like to ask Prof. Allen if he would use slag or railroad cinders for the surface of a road, or whether he intended it should only be taken for the bottom layer of a road? It seems to me it is very objectionable to put it on the surface of a road. It is also poor railroad ballast, and only a road poor in ballast would use it.

PROF ALLEN:—I would not hesitate to use furnace cinders for the surface of a road where good gravel could be obtained only with difficulty, and I would not hesitate to use slag as a substitute for broken stone.

MR. J. R. FREEMAN:—Mr. President, as a comparison between cinders and gravel, I may cite the case of Canal Street in Lawrence. The one-half of that street north of its center line is used by the mill corporations while the southerly half is owned and kept in repair by the Essex Company. The mills used to repair their half of it by covering with cinders or "clinkers," while the Essex Co. repaired their half with gravel from the river bed and after a very little time the road that was covered with cinders became very dusty and full of ruts and pockets, and very much inferior to the gravel road, so that in that case it showed in a very marked way the great superiority of a good ordinary gravel road over a cinder road.

MR. W. E. MCCLINTOCK:—In one case where we had much sand and mud I put on ten thousand loads of ashes and covered it with cinders. They powdered up and got dusty and in wet weather, very heavy. We had finally to cover it with stones to get rid of the dust. It was very much the same with the shell road between Portland and Deering, Maine. The road became very dusty and after a few years the dust almost ruined the foliage of the trees. The houses in the vicinity were discolored and turned yellow and the dust became such a nuisance that the road was covered up with something and the dust got out of sight.

MR. E. W. HOWE:—Mr. Chairman, I am down for the discussion and not for a paper I believe. I do not know that I can add anything to what Prof. Allen has said as to the foundation of a road. In the construction of the surface a question arises, as he suggested, as to the choosing between Telford and macadam foundation. It seems to me that it is largely a question of expense, but in most cases I should be in favor of the Telford foundation. Assuming that the depth of the stone is the same in either

case, the Telford road has the advantage that the lower two-thirds of the stone does not require crushing and is put in place without the expense of watering and rolling.

Having laid the Telford to foundation how should it be covered? My experience has been almost entirely with park drives where the traffic is light though, during the process of construction we are obliged to use the finished roads in hauling heavy material so that they do get considerable hard usage. It seems to me that a very thick covering is unnecessary and is simply a provision made for neglect. In our experience on the Boston parks we have made what we call a Telford road (I suppose it is not strictly so) of nine inches of Telford foundation and then three inches of crushed stone, making twelve inches in all, no allowance being made for the covering of binding gravel or screenings which generally does not add to the thickness of the stone. This three inches of cracked stone I think is as good for light traffic as three times that thickness would be. The main point of the matter is in the care of the road after it is built. If no attention is given to the road after it is completed the thin road will soon go to pieces. The road which is made with a thick layer of crushed stone will probably last longer without becoming utterly impassable but if it is kept in perfect condition the expenditures for labor and material will be as great as for the thin covering.

For finishing the surface the use of stone screenings alone or their use with some clayey material is a matter largely of time and expense. It is possible to bind a road with the toughest and hardest materials, but it costs money and takes time and so we add a very little clay or clayey gravel to the screenings; the clay helps to hold the moisture and the road does not get dusty as soon. We have however built some roads with no binding material whatever except the crushed stone.

The question of using screenings for binding material comes up in considering the matter of maintenance. If the road is kept clean, the material scraped off and that which collects in the catch basins is very good for binding, and for repairs of walks. As to the cross-section of a road I can see no reason for the rounded crown that most authorities advocate. If we need a steep pitch on one part of the road, I do not see why we do not need it on all parts, and as for the straight pitch making a ridge in the centre of the road, that is more theoretical than practical. I should give the grades for a straight pitch. If there is a flat place in the middle and consequently a steeper pitch on the sides the traffic will take to the middle and the wear will make that hollowing, a place for the water to stand, while if the road everywhere has the same pitch, there is no temptation to travel on one part more than another.

I think one fault in covering roads is that too much covering material either of binding gravel or screening is frequently used. I would use the smallest amount necessary to make a firm surface and then maintain the road by adding material a little at a time where it is necessary.

In maintaining roads, I think that very often one great fault is in the method of watering. The usual method about here is to let out the watering to contractors at so much per mile or street for the season and their

object, of course, is to get the work done with the least labor possible, and the result is that they use watering-carts with the coarsest sprinklers they can and soak the road. The road is then in a condition such as it would be after a hard shower, and if the road is watered constantly and not allowed to become dusty it is soon in the same condition it would be if we had rain every day. If the covering is thick it becomes mud and the road soon goes to pieces. The watering-cart should be used with a fine sprinkler and the road gone over often; water should not be put on in such quantities that it will run in streams on the road. To do the work with a fine sprinkler costs more money than it does to give the road a regular soaking two or three times a day, but it does not injure the road.

I had some figures prepared as to the cost of the style of road I have described. I do not know that they are of much interest. Probably many of the members present who build roads can make them for a good deal less money as it is well known that city work done by the day is not always the cheapest. But for the last year we have kept a pretty good account of the cost of our twelve-inch Telford road and we have found that the total cost averages about ninety cents per square yard. That includes everything, quarrying, crushing and hauling the stone, placing the stone and breaking it down, rolling, watering and procuring of binding gravel.

The next subject that occurs to me is the cost of maintenance. On the park roads we do a good many things which strictly do not belong to the maintenance of a road. The roads are divided up into sections giving one man a section about six-tenths of a mile in length. He is to keep that road clean, to make such repairs as are necessary, keep the walks in order, trim the borders, and generally to keep the grounds in the immediate vicinity of his section of road clean and free from rubbish. So that I am unable to give the cost of cleaning the roads separately. But the cost of watering, I have kept carefully this year. With the fine sprinkler on the watering-cart, the cart to go over the roads in dusty, hot weather ten times a day instead of twice, and we find that the expenditure has been $721 per mile, of which the water was $187 and the teaming $533. The repairs have cost a little less than $200 per mile, the stock used having been entirely screenings from the stone crusher. The cost of the screenings has been $129, teaming $49, and labor $20. The practice is never to allow a hole to come in the road, but as soon as there is a hollow that the water will stand in, the man in charge sends for screenings. Sometimes he has them piled near by so that he can use a wheelbarrow for carrying them. If the material is not within wheeling distance he sends for a cart and goes over his section probably using up a cartload each time excepting after very heavy storms and in the spring of the year when larger surfaces have to be covered. I think our experience warrants the belief that the cheapest way to maintain the roads is to continually follow up the repairs. I know that one distinguished authority claims that the better way is to allow the road to be entirely worn out and then build it over. This involves the closing of the street, picking up the surface, adding new material and re-rolling. But I think that in the maintenance of a road by the "stitch in time" method there is no occasion to close it to

travel (a great inconvenience in many cases) to pick up the surface or to re-roll it. We have maintained roads in as good a condition as when first built for three years and there has never been a roller on them, nor has a pick been used. I see no reason why we cannot continue to so maintain them for many years.

MR. F. L. FULLER:—I would like to ask Mr. Howe a question,—How much the water costs a thousand gallons that he spoke of in referring to the expense of water?

MR. HOWE:—It is sixteen cents a thousand gallons where a large amount is used.

PROF. WM. WATSON:—When the road is thin and the cost of maintenance goes all on time, whether that cost of maintenance is not very much increased when the road-bed is thin, and whether extra thickness would not decrease very much the cost of maintenance?

MR. HOWE:—That depends very much on what you call maintenance. If you wish a road kept in perfect condition all the time, I don't think the cost of maintaining the thin road is any more than that of the thick road. If you allow that the road needs nothing done to it until there is a hole six inches deep in it, the cost of the thin road will be the greater. If you have one foot of macadam on the road you won't get through your macadam as soon as would be the case if it was thinner, but if you want a perfectly smooth surface all the time I do not see any advantage in the extra thickness.

MR. S. SMITH:—Can Mr. Howe tell us something of the tiles for drainage on the park roads.

MR. HOWE:—They are all under-drained. Sometimes the fill is made of coarse stone, and no drain is needed on the uphill side, and in other places we lay two drains one under each gutter. Some of the roads have the walks parallel with and adjacent to them and others are not so arranged, the walks being run at some distance. Where there is no walk bordering the road there is a tile drain under the gutter.

MR. H. H. CARTER:—What is done with the covered surface of the road when ground into dust in dry weather? Whether it is swept up or left on the road?

MR. HOWE:—We do not sweep any roads. We scrape them sometimes when they are first built and too much binding material has been put on. We have had to scrape some of it off after it began to be used, but that was due to poor workmanship. Some of the material is worked down into the surface and helps to bind it while the balance is washed by the heavy rains into the catch basins which are cleaned out as they become filled. The material removed from the basins is sometimes used for binding on new roads and sometimes for repairing walks; this use could not be made of it however if the roads were not kept clean.

MR. F. P. STEARNS:—Is there any difference in wear in the course of two or three years?

MR. HOWE:—We have no means of knowing what the reduction of thickness is, of course, we maintain the road all the time and are continually adding material to it. Whenever the stone becomes bare it is at

once covered with new material. The patches seen on a road after a rain are generally so small that the travel does not avoid them and they all disappear in the course of two or three days. It is not like dumping a cart-load of material on the road and having all approaching teams turning out around it. It is rarely that any sign where these patches have been made can be seen after the material has been on them three days.

MR. WILLIAM E. MCCLINTOCK:—The first question to be considered in either constructing or maintaining roads, is the material.

My discussion is to be solely on improved ways, as we are now seeking to popularize the subject of road improvements by placing it within the power of towns having small annual appropriations to have good roads.

I shall divide my subject into four classes, viz.:—concrete, macadamized, gravel and dirt.

Concrete, I shall not discuss much, for the reason that good work is very expensive, and poor work is not worth the laying at any price.

The bed should be thoroughly compacted and drained, a good foundation put down, and the top or wearing surface should be of good materials, properly proportioned and put in place. Concrete loses its vitality after about five to seven years, by the evaporation of the more volatile oils and will crumble away leaving the stones to project in such a manner as to give an exceedingly rough surface, finally coming out altogether. To remedy this the surface should be coated with a thin coating of tar before the crumbling starts.

The great enemy to this class of work is the digging of trenches for sewer, water and gas. It is next to impossible to replace such trenches and leave a good even surface.

There are many roads, where the travel is light and free from heavy teaming, and the grades are good, where gravel gives a good road.

Gravel may be water-worn and so free from angles as to be absolutely incapable of packing down without some binding material. If placed on a road and travel turned on, the action of the wheels slowly abrades the larger stones or crush the smaller ones until enough stone dust is furnished to bind the whole together. The resultant road is hard and smooth, but as a rule, out of all shape, as the wearing out and subsiding process is carried on very unequally.

It is far better in using gravel of this description to mix some binding material with it, and in so mixing, it is well to bear in mind that all binding material is an evil and should be just as sparingly used as possible. What is wanted is to fill the voids, and no more, and form a matrix in which the stones are bedded.

While this makes a splendid dry weather road if properly mixed, it muds freely on the surface, as there is not sufficient body to the smaller stones to hold up even under light carriage traffic. Another kind of gravel is made up of angular stones and a natural binding material like the blue gravel of Lynn and red gravel of Medford. These have simply to be carted onto the street and slightly compacted in order to give a hard, smooth surface.

Such roads, however, are very muddy during wet weather, and are, as

a rule, short lived, as the gravel is crushed by the traffic and turns to dust.

A third gravel road may be constructed, where the mixture must be made, and contains an excess of binding. Such material can be used to great advantage on steep grades, say above 4 ft in 100, where the surface becomes gullied by storm water. This class of street I have found to be the hardest to maintain.

By sloping the road bed to a proper crown with a good hardpan, or even a still poorer material, and then covering with about two to three inches of clean gravel, with the smaller stones screened out, and rolling thoroughly after a heavy rain, the result will be a surface that will withstand any amount of wash. In the spring after the frost comes out such a street may be muddy, but by covering with a second coating of perhaps one or two inches of stone, it will stand for years.

This is applicable only to roads having a grade sufficient to carry the storm water quickly to the gutters and sufficiently free from shade to allow free action of the sun for drying after a rain. Don't try it on a flat or shaded road.

There are long stretches of road, where the town has but a small annual appropriation, that must be treated at a slight outlay. Here we find the gutter dirt, sods and all, thrown into the middle of the street. This upheaval work was formerly done by hand, but now it is done more expeditiously and cheaply by road scrapers.

One thing must be borne in mind in carrying out this class of work, all loam and sod are porous and absorb a great deal of water. The water softens the mixture and makes mud, which dries very slowly, and during a wet season has hardly time to get dry before another wetting.

Now, if we should take some of the money saved by using a road-scraper and devote it to covering some of the roads made in this way with stone, the result would be surprising.

Of course any material that holds a large amount of water is heavily acted on by frost, and the only remedy for roads that quag in the spring is to carefully under-drain and get rid of the water. Water, either on the surface or under, is the great enemy of roads, and will destroy every time. This is a case where total abstinenee (from water) is a necessity.

We now come to macadamizing, that is destined to be the economic and popular manner of building roads.

I shall divide macadamizing into three classes; Macadam proper, Telford Macadam and American Macadam.

Whichever method is employed the wearing surface must be the same, and thus the different methods simply become different in foundations.

In the foundations any angular stone can be used, but in the wearing surface we must study the material carefully.

We find in this vicinity, trap rock, pudding stone, granite, porphory, green stone and field stone.

The trap-rock, porphory and green stone are very hard and break into good shaped cubes that pack together into a firm mass.

Granite and pudding stone make fairly good road metal, although not in such good shapes or so desirable as the first named.

Field stone can be used when none of the others are available.

They come as a rule of unequal quality and break with a large percentage of spalls or flat pieces and give an excess of dust.

While discussing the metal perhaps it will be as well to take up the question of breaking and preparing for use.

I shall refer to oscillating and rotary crushers, crushers set up high, with rough stone raised to crusher and broken stone dropped into pens, pockets or carts; and crushers set at the ground level with elevators to deliver the broken stone into pens or into pockets.

The crushers most in use in New England is of the oscillating pattern, such as the "Blake" or the "Farrall and Marsden," and are too well understood to need any description.

The rotary crusher "Gates" consists of a heavy core casting with a central spindle carrying the corrugated breaking surfaces. The spindle is fixed at the top while the bottom is given a revolving and at the same time sideway motion by an eccentric shaft. The oscillating crusher, breaks the stone and then draws back, allowing the stone to drop down ready to receive the thrust of the jaws on their next forward push.

Time is of course lost while the jaws are gathering for a new stroke, and more power is required to start against a lot of stone with no momentum.

In the rotary crusher, no time is lost as the action is continuous and the momentum continuous.

After a careful record of several years I find that stone can be broken by a Farrell and Marsden crusher, for practical work for from 20 to 25 cents per ton, while the cost of stone on the street is from 90 cents to $2.00 a ton.

I will give a record of one year in my own experience as to the itemized cost of getting stone on cart ready to haul onto the street, giving the cost per ton.

Stone at crusher..................................	$ 1.00
Running..	
Feeding..	
Water..	
Fuel...	
Oil etc..	
Repairs..	
Loading..	1.13½

In the course of my remarks I have referred to breaking for practical work and I want to say a word on this subject.

I have no doubt but what with a 15×9 Farrell and Marsden crusher, and a twenty horse power engine, 100 or 120 tons of stone could be broken in one day, at a cost for that day of say $7.50, making the cost per ton for breaking 5½ to 7½ cents. This amount includes nothing for repairs, loss of time or miscellaneous items.

While we may break 100 to 120 tons a day, our work may not be so as to allow of our caring for more than 50 or 75 tons. In such an event all we break over and above what we can care for must be handled over at least once, and probably twice at a cost of from 15 to 25 cents per ton.

This introduces the whole subject of the most economical manner of setting up a crusher.

If there is a ledge hill which will permit of setting up high, without handling the stone but once, pockets can be constructed to take the stone from the screen under the crusher and high enough from the ground to allow a cart to drive under, and having gates to draw the stone from the crusher to the cart without a second handling.

In setting up this way, the stone supply should be at or near the level of the feed opening, or above, to allow of cheap delivery. By this, I mean that the platform should be so arranged as to allow the person feeding to throw directly into crusher without lifting the stone above the knees; it should also allow of driving teams to dump directly at the crusher.

There should be four pockets for as many grades of stone and there should be a clear space under these pockets of at least 8 feet at allow the broken stone to fill the cart without assistance of man with rake.

The labor to run such an outfit would consist of one engine driver and two feeders, or three feeders if more than 70 tons a day were broken. The cost of setting up would be from $300 to about $600.

The details of setting up must be determined in each case, only bearing in mind that with an oscillating machine the motion of such a heavy mass requires a solidly framed and built support, if of wood. I am inclined to the belief that the most economical setting up, figuring all the details, is one that sets the crusher upon or as near the ground level as possible, where the stone can be teamed to it without a steep incline, drawing full loads every time and having an elevator to take the stone from the crusher and deliver into elevated pockets through a screen. The first cost of such a set up would be about $1,500 to $2,500. Its advantages would be, ease of access, convenience for work and adaptation to any locality. The last, adaptability to any location is a very great advantage, as by locating in the right place saving can be made not only in delivery to the crusher but also in cost of teaming to the point where used.

It is not my present intention to particularize on this subject, but I think enough has been said to show that the matter of setting up is an important one and demands a careful study.

This subject opens up the broad question of how to get the best results for the outlay on our highways.

We have already spoken of having no water.

Water in a road foundation allows the same, if it be clayey or loamy, to be pressed up and through the interstices of the stone, and it is only a question of time when the mud is on top, while the stones are at the bottom.

Drain tile, blind drains or coarse stone should furnish free passage for the water and proper means should be furnished to convey it away out of reach.

However thick or thin the coating of stone, the bed should be shaped with a proper crown and thoroughly compacted to allow any water that may pass through the stone to flow to the gutter or to some drain.

This is a vital point, more particularly so with thin roads, and if omitted will give trouble, cause expense and cast discredit on the work.

There is a hard pan, found in the vicinity of Boston, that gives a thoroughly solid foundation. All it needs is shaping and crowning and a thin coating of stone to give an excellent road at small expense. A wearing surface of from 4 to 6 inchesof good metal will give as good results as a Telford road, and, in my opinion, last longer.

If it is within the power of an Engineer to give good results at reduced cost, he surely is derelict in his duty if he fails to accomplish the saving.

It is a waste to build bad work, but it is equally a waste to put in more than is needed.

The old housewife's rule for making brine for pork is, "put in salt enough so the salted water will bear up an egg, then throw in another handful."

I have often heard the criticism on American macadam roads I have built, "he don't know how to build a street, why, I have seen them in England where they put in two feet thick of stone; that thin coating will not be good for anything."

Now with all due deference to English or French practice I feel that we may possibly improve with age, and all the features must be studied before we decide on the merits of any scheme.

The surface is what gets the direct wear, and the length of time this will wear, depends on the quality of the metal and the amount of tonnage over it, no more, no less.

Superintendence.

When we speak of Franklin, Washington, Grant, Newton, Gladstone, Longfellow, we need not describe them by their christian names, or recite their deeds in order to make one understand who we mean.

There never was but one of each kind, and the mere mention of the name calls to our minds instantly the genius, patriot, soldier, student, statesman, and poet. Nature may give one talent, but she is not so prodigal as to give more than one to each individual.

The sword of Grant in the thick of battle, would be of no more value than one wielded by any brave Lieutenant; but the Lieutenant's sword would be infinitely more effective when wielded in a battle directed by a Grant.

You have all heard of the inventive crank who put together a series of wheels, pinions and levers with one main wheel to drive them, which combination constituted a complete perpetual motion, with one exception, and that exception was, keeping the main wheel in motion.

Now, this is exactly our position in all of the smaller communities. We are putting our general into the fight, when he has not the power to

direct, as his energy is entirely absorbed otherwise. We have wheels, pinions and levers and also the big wheel, but we do not apply the power to that wheel.

If you want a man to superintend your street work, you take a farmer, a stable-keeper, an expressman, or in fact, anybody who has driven or had the care of horses. Your men may be honest, industrious, and able in their line, but their experience does not extend to men and materials.

They do not know where others have tried and failed, and they consequently go on in the dark until you get thoroughly dissatisfied with results, and perhaps, just as they begin to get a little insight into the work, another man is set up to be tumbled over.

If you but look into this matter carefully you must perceive that it is all wrong. Colonel Pope's splendid gift to the Institution of Technology is bound to result in great good, but no school can give experience, no profession can give brains to a student or show him how to get over rough places. General experience can alone do this.

Many of our best and ablest practical men have large experience, but could not even pass the first examination to our Institute. How are we to reach these men and teach them how to select their materials and how to combine them in the work to give the best results?

This is what we need and I think we can obtain it.

First, select the man who is active and able to manage other men and direct them in a way to get the most work. This man is to be our student and receive instruction in securing the best materials and handling the same after he does get them. This man is your Superintendent of Streets, and to him you must look for an honest and economical expenditure of your appropriation.

Now, our school is formed, the pupils in their places, though scattered, and ready to receive instruction.

This instruction can be had from men who have had practical experience in this class of work, and we introduce them to you as Highway Engineers.

Your highway engineer can be employed by the year, and his duties will be such that he can advise with from ten to twenty towns, and each town will therefore have a small amount to pay annually in order to secure proper supervision.

It shall be the duty of the Highway Engineer to consult with and instruct the local Superintendent in the selection and combination of materials and the methods of construction, and power must be given him to enforce his views.

I think that I have said enough to explain my ideas, and it remains with such organizations as ours to so mould public opinion as to compel official action.

Some will offer the objection of additional expense, but remember a saving of from 2 to 3 per cent. on your annual road expenditure will pay the cost and the same can be more than made in direct terms, leaving out the saving in wear and tear of teams and general efficiency in team power resulting from good roads.

THE CHAIRMAN:—Mr. McClintock's remarks ought to call forth others. Are there any remarks?

MR. SIDNEY SMITH:—I should like to ask Mr. McClintock if he has ever known a sewer or water pipe in a street to be disturbed by any of these fifteen-ton rollers?

MR. MCCLINTOCK:—I know that question has been raised, but it seems to me absurd. In the first place, the fifteen-ton is distributed over seventy-two inches. An ordinary coal cart carrying two or three tons bears heavier going over a sewer than a heavy steam roller. The only advantage in a steam-roller is that you can do the work quicker than you can with a coal-cart.

MR. HOWE:—What is the description of road costing $1.25—what thickness?

MR. MCCLINTOCK:—The figures I gave are a rough estimate,—$1.25 for the Telford road from fifteen to eighteen inches thick. That of course, would include everything but the sub grading.

MR. DWIGHT PORTER:—Is there any more jarring from a steam-roller than if the pressure is not so much?

MR. MCCLINTOCK:—I think there is. The clerk of the Water Board in Chelsea, reported that a water pipe had been broken by the jar of the steam-roller, but unfortunately for that theory, the roller had not been on that street at all. Our water pipe is thin iron lined with cement, and that of course, had rusted out in places and breaks very easily. We have not had one break where the roller has been at work, although we have had an average of one hundred and twenty-five every year throughout the city.

MR. DESMOND FITZGERALD:—Have you ever considered the question of the proper height of curb-stone?

MR. MCCLINTOCK:—I don't know that I have. We set ours to show seven inches, except where the grade was flat. Our minimum gutter grade was six inches to the hundred feet and with a flat grade, the additional fall was given in the gutter, showing from five to eleven inches of edgestone.

MR. FITZGERALD:—I never understood our putting our curbstone as high as we do. It makes a great difference in the convenience of people stepping off into the street. I was in Paris in a very heavy rain storm, almost as heavy a rainfall as I ever saw in Boston, but there was no difficulty in carrying the water off. I suggest that as a matter of discussion.

MR. MCCLINTOCK:—You have different conditions here,—snow etc. In snowy weather we have had trouble with the gutters filling and flowing over the sidewalk. That is the only case where the deep gutters are an advantage.

Mr. FITZGERALD:—In Montreal where they have deep cuttings they let the snow accumulate three and four feet deep over the road and gutters.

MR. HOWE:—I think at Franklin Park we had some figures as to the cost of steam and horse rolling. Our experience began this season, and I think Mr. Putnam can give the results.

MR. C. E. PUTNAM:—It used to cost thirty-nine cents to roll it in proper shape with horses, and we do it now for about twenty-eight. Of course, that includes the water and the putting on of binding material.

In regard to the steam-roller injuring the pipes, we built some catch-basins, a basin on each side of the street, and before the basins had been built a week we finished the street with the steam-roller, and in some places the basin projected slightly under the street, but that was at a depth of 2½ or 3 feet below the surface, and while we were finishing the street there was no injury done to the basin.

Mr. Carter asked the question about the dust. We find by wetting the street lightly there is no dust, that the dust is kept down all the time until there comes a rain which washes it away.

MR. MCCLINTOCK:—As to the cost of steam-rollers I think I estimated this year in some work I did that it was about six cents a yard on a street with an average depth of stone equal to six inches, and the actual cost did not vary much from six to eight cents a yard by the steam-roller. That includes the water, but not the binding.

MR. ALBERT F. NOYES:—Mr. Chairman, I do not know as I can add much to what has been said, more than possibly to reinforce some of the statements made.

My experience and observations coincide, to a very considerable extent, to those of Mr. Howe and Mr. McClintock.

In regard to the relative merits of horse and steam rolling, I have been, and am still a strong advocate of the use of the steam-roller.

At first, it was because theoretically and practically I thought that from the thorough consolidation of the material in the road-bed, it must, and did give the best results, but from my observations, of the wear of the road, I find that the surface usually wears more evenly when rolled with a ring horse roller than with a steam-roller. Now, there may be some detail of construction of the horse rolled road, not included in the construction of the steam rolled road, but so far as my study has been made, I am led to conclude that it may be due to the placing or wedging action of the rings of the horse roller on the broken stone not obtained from the broad, flat roller of the steam-roller. I have felt that the same effect could be otained by placing ring rolls on the front wheel of the steam roller.

The steam-rolled road, I have known in many cases when gradually wearing out, to become slightly undulating, and to need a greater amount of repairs, than when thoroughly horse-rolled. The expense of operating steam-rollers is so slight, that having a steam-roller, a town will generally use it in preference to horses. Therein it has its redeeming features. Possibly the other members here have observed these conditions and may be able to give a better explanation, or it may be that the observations which I have made or rather the results, are due to some neglect in the use of the steam-roller or the placing of the material.

Too much emphasis cannot be placed on the value or importance of shaping and thoroughly rolling or consolidating the foundation of the road bed before applying the Macadam.

It is surprising how an apparently hard surface can be settled or compressed by the steam-roller, and it certainly gives a more even thickness of stone and a solidity which will prevent the material working up through the stone, thereby giving unevenness to the finished surface of the road after it has been subjected to a little wear.

I feel that it is desirable to use as little binding or surfacing material as possible. Careful observation on this point, so far as my judgment has determined, shows the poor economy of the thick coating of binding material.

If the money spent in getting and applying the surfacing material, could be spent in more thoroughly compacting the foundation and then watering and covering the stone with just as thin a coating as possible of the dust (which I prefer) I think better total economical results can be obtained.

The complete drainage of the road bed is of the greatest importance and is often neglected. As Mr. McClintock says, in the smaller cities, we have to deal with roads to a very considerable extent as we find them.

They are often constructed by ploughing out the material in the sides and scraping it into the center, thereby giving a road bed with double the natural thickness of loam. As it becomes worn out and muddy, a coating of gravel is put on which soon becomes mixed with the loam. While this tends to make a good summer road, it is almost impassable in spring, and the result is a demand to have it re-constructed.

Our plan has been to excavate all the loam material beneath the gravel and in many cases it has become so thoroughly mixed with the gravel, it is almost impossible to say where the dividing line should be. I have had a number of cases where this could be attempted only at very large expense, but we have met with very good success by constructing, on the side generally adjacent to the slope of a hill, a blind or leaching drain, thus intercepting the ground water from flowing through the road bed.

The early practice used to be, to make a rubble stone culvert or drain, but this was very expensive, requiring rubble walls of eighteen inches to two feet thick, and two to four feet high, according to the amount of water they had to carry. Of late years, I have adopted the practice of using tile drain or sewer-pipe laid with open joints and filling round the pipe itself with a course of pea gravel to the depth of from six inches to a foot around and above the pipe. The rest of the trench is filled with stone. Those have worked in every case with very good results. Where the road has been almost impassable in the spring, we find that the trouble has been entirely removed and the road put in good condition at comparatively small cost. I have used tile pipe as Mr. Howe describes in his park roads, but I have hardly felt I got their full value at so slight a depth.

The question was asked, if the Macadam even when kept in constant treatment did not wear out? I think it does. I have observed when excavations have been made in Macadam roads whose surface has appeared to have been kept in perfect condition, there has been a very appreciable loss in thickness of stone. At times it has been worn down to a thin crust. Enough attention is not always paid to location.

Cases can be often observed in all our cities, where poor judgment has been used in locating with excessive grade, which makes it not only expensive to keep the surface in repair, but an extra cost for every load of material moved over it.

In reference to the slope, I think that ground has been fully covered, but it should, in my judgment, be so as to induce the traffic to pass all over the surface rather than in any special rut.

In Newton we are sometimes criticised as constructing roads with too level slopes and perhaps justly in some cases, but the travel goes all over the road, and it wears it much more uniformly,—one-half of an inch to a foot or one in twenty-four is the fixed slope.

I have observed very good results obtained by rolling earth roads. I presume Prof. Allen means a loam road. It would be, I should say, a mixture of loam and gravel,—a light coating of gravel put on a dirt road.

The sizes of the surface stone and also the stone screenings for repairing the road should be regulated entirely by the traffic put upon the road. You have to repair with a stone practically two and one-half inches in diameter for a heavy traffic. If you do not, my observation is, that it soon becomes ground to powder. Even then a two and one-half inch stone will need a good backing to make a good road. With lighter traffic an inch and a half to an inch stone with an exceedingly light covering, almost dust.

MR. F. L. FULLER:—I would ask how the edge-stones in Newton compare with the height of the centre of the street?

MR. NOYES:—Our rule is nine inches for the depth of the edge-stone. There is one-half an inch slope to the sidewalk, and one-half an inch slope to the street. This will make the edge-stone the same height as the center of the street for a street of fifty feet wide and three inches higher than the center of the street for a street forty feet wide. This rule is subject to special modifications under different conditions of the slope being increased on steep grades and diminished slightly on flat grades. It was adopted for the assistants to work to, and is so simple they are not apt to make a mistake.

MR. FULLER:—Is your sidewalk any particular proportion of the width of the street?

MR. NOYES:—Yes, sir; one-sixth of the width of the street. In a narrow street I should make a sidewalk wider. I should make it in a 30 ft. street, six, or six and a half feet wide.

MR. FULLER:—You would not have anything narrower?

MR. NOYES:—No, sir; I would not. If our rule for width of sidewalk should be changed, there would be some modification increasing their width.

MR. MCCLINTOCK:—In the early part of your talk you refer to the surface wearing more evenly when rolled with a horse-roller than with a steam-roller, I would like to ask whether that shows on a street where the stone has been properly screened into equal sizes, and whether in the depositing on the street the stone is dumped into a mass or not. I do not know why it should exist more where a steam-roller is used than where a horse-roller is used.

MR. NOYES:—I do not know except that I have observed it in the streets which I had reason to believe were carefully made,—that is, stones of uniform size used, but as to the dumping the material on the street, I cannot say. Although I believe it was spread. The dumping of the material from the cart on the road being constructed or repaired, should be avoided. I have noticed many times that you can count the places after the road has begun to wear where the loads were dumped.

I noticed a neat contrivance used in Worcester by the Superintendent of Streets. It is called a dumping board, the platform on which the stones are dumped from the carts. It is about square and somewhat wider than the cart. Every load is dumped on it and the spreaders are obliged to spread from it. There cannot be that chance of leaving one place more consolidated than the other portion.

MR. DESMOND FITZGERALD:—The country towns have a bad habit of ploughing up the grassy sides of their roads and casting the loam and sod into the middle. A good country road is the opposite of this. The turf on the sides keeps the road from washing, saves dust, and is beautiful. I have had occasion in consultation to recommend building country roads with a narrow but good piece of gravel construction in the center flat and well drained and turfed with sides of considerable width and at a good slope. Such a road may be wide and costs but little to maintain. In the maintenance of the roads around Chestnut Hill Reservoir, which have quite a reputation for smoothness, I have found it advantageous to flatten the slopes of the roads as much as possible. This course saves much on the sides where the water accumulates in quantity and velocity as it runs off. I have gradually reduced the cost of maintenance to about $900 a mile, including watering, but I pay nothing for the water. For heavy travel, the less covering put on the rolled macadam the better. There is nothing like crushed stone screenings for this purpose.

MR. A. H. KIMBALL, OF HINGHAM:—The last gentleman alludes to letting the sides of the streets where they are wide grow up to grass as being the most economical way of keeping them in repair.

I think it is a mistake that back roads in the country are often built too wide.

Where the travel is all on one track I prefer a road 20 ft. wide in good repair to one 30 ft., with from 5 to 8 ft. between the traveled part and the gutter growing up to grass and often brush.

Much has been said (and well said) this evening in regard to road building. I wish to thank the society for the invitation to be with you and the benefit I have received from the discussions.

Last year I rebuilt a piece of road with crushed stone; the stone was furnished by Mr. John Beale, who has a crusher located near the town line of Cohassett and Hingham. The cost of the stone was $1.00 per yard at the crusher. I first properly graded and drained the street. Before any stone was carted the surface of the street was all loosened up with "Babcocks's hardpan plow," which I think is much better than to place the stone on the old hard road bed. I was careful to have the road graded so that when covered with the stone they would be of an even thickness.

Then the stone was drawn, and every load dumped on a platform (which has been mentioned here to-night, but does not seem to be in general use).

This platform is made of 2 inch fence plank cut 7 ft. long and bolted to the underside of two pieces of 4×4 in. spruce 10 ft. long, so the planks lay on the ground, and the pieces to which they are bolted answer for the sides, to hold the stone on the platform when dumped, which is done by driving the team over the platform and stopping the cart so as to dump the stone on the centre. The stone is then where it can be spread more easily than if dumped on the ground. In spreading I use an eight tined stone fork, which will take up the coarse stone, leaving the fine stone on the platform, from which they are removed with a shovel and placed on top of the coarse stone, which is nearly equal to screening the stone, and they are sure to be all overhauled. Then one man at each side of the platform by hooking the shovel to each side will draw it forward ready for the next load. The stone was rolled with a section roller weighing 2½ tons, drawn by horses.

The stone was covered with about an inch of clay gravel, screened and spread from the platform, and then rolled, increasing the weight of the roller to 5 tons as the road grew harder.

It was necessary to put on the binding material the second time in a few thin places.

By the use of the platform and stone forks the fine stone being on top very little binding material was required.

Water for wetting while rolling was applied by the use of hose with sprinkler, and attached to the hydrants.

I think many mistakes are made by using too much binding material on a macadam road. I have observed that any more than is necessary to hold the stone in place has to be carted away before a clean, smooth road can be had. I tried clay as a binder on a short piece of road this year, with very unsatisfactory results.

The road above described was 30 ft. wide covered with stone 8 in. thick on the center to 4 in. on the sides. The cost per square yard was 47 cents. Something has already been said about making material hold on steep hills. I have had satisfactory results from using a layer of clay first, and then a layer of dry screened stone gravel, when it would have been almost impossible to make it stay in place without the clay. This was on ground with a sandy bottom.

Of course the same rule will not apply to all cases, any more than the same kind of gravel will be good for all roads; but it is necessary to mix it with binding material according to the condition of the road on which it is to be applied.

MR. THOMAS ASPINWALL:—After listening to all that has been said this evening, I feel that any remarks of mine would be little more than words and add but slightly, if at all, to the interest of the meeting.

I have taken great pleasure in listening to what others have said, and Mr. McClintock, especially, has given much comfort to my soul in his remarks concerning *thin*, or as he calls them, "American macadam" roads.

My partner and I have been trying an experiment in this direction, and although the experiment has not yet reached a stage when it may be called decidedly either a success or a failure; still it may be said that we feel justified in entertaining strong hopes that it will be the former. The case was this. About two years ago there was put into our hands the problem of developing for building purposes the territory in Brookline, well-known to many of those here to-night as Corey Hill, and as a matter of course, the land at that time being mainly used for pasture, a prime necessity of the undertaking was *good roads* at the lowest possible cost. The material to be found on the hill consisted principally of "hardpan," by which I mean a hard clayey gravel, but mingled with this we found a large proportion of boulders of various sizes, from that of a man's head to stones weighing several tons. The hardpan was obviously of no value as a material for surfacing a suburban street, and suitable gravel was not to be found within a distance of at least a mile. Gravel in Brookline is not easily found in the first place, and in the second, even that of indifferent quality is very expensive. Moreover, our experience in building gravel roads through another property near by, where the formation was similar to that on Corey Hill, had not been so satisfactory as to encourage us in adopting that method of construction a second time. On the steep grades, averaging perhaps five per cent., which were unavoidable, we had found it practically almost impossible to maintain gravel roads in the condition necessary to make them attractive to pleasure travel and intending purchasers of lots.

At that time the Bridgeport roads were not known to us; nor, of course, had we seen the very interesting letters on the subject of thin macadam roads which appeared from the pen of Mr. Edward P. North, M. Am. Soc. C. E. in the *Sanitary Engineer* last winter; but after a good deal of thought and drawing of specifications, we made up our minds that six inches of broken stone, if properly applied, would answer the purpose, and accordingly our clients were advised to adopt that method. It was recommended also that, inasmuch as the roads would necessarily be much injured by digging of trenches for water service pipes, sewer connections, etc., consequent upon the erection of houses, the surface be finished temporarily six inches below the established finished grade, thus allowing a full depth of twelve inches of broken stone to be laid after building operations had ceased and the roads were exposed only to legitimate traffic. This, of course, would necessitate doing some of the work over again, such as the raising of catch-basin stones and manhole covers.

The sidewalks, however, were to be brought to finished grade, a grass border between the walk and the carriage way allowing this to be accomplished without difficulty.

A section of roadway 700 feet long and 24 feet wide, with a grade of seven per cent., was completed and looked very nicely, promising to be a great success; but it was scarcely done when it was decided to have a sewer in the street, then water pipes, and it is scarcely necessary to say that the effect upon the road was disastrous. The sewer, eight feet deep, was laid about on the centre line and the water pipe, five feet deep, on one side of

the street, while active building operations were carried on upon the other side, the travel being thus forced into the centre of the roadway and upon a very narrow track. In constructing the sewer we had water enough to give some trouble in jointing the pipes, but not sufficient to puddle the trench, and it was found to be impracticable under that contract to obtain satisfactory ramming during back-filling. As a natural consequence the sewer trench settled, making a *gutter* in the centre of the street, down which a large quantity of water flowed at every rain.

For the reason that the road was to be used largely for construction purposes at first, it has never been repaired since the sewer and water pipes were laid, and if the method followed were to be judged by the condition of this section to-day, there would be no hesitation in adopting some other plan.

In the remainder of the work it has been practicable, however, to lay the sewer, water pipes, and surface water drains before applying the road metal; to compact the trenches more thoroughly and to roll the sub-grade more satisfactorily. Unfortunately, a steam-roller is not at our command, as we wish it were, but notwithstanding this disadvantage the prospect of success is very enconraging.

It should be stated that the stone for the macadam is obtained from the boulders encountered in the excavation, which is very large in amount owing to the necessity of cutting down the summit of the hill to fill a valley at the foot. The stone thus obtained is hard enough, but does not crush into the most desirable form; the tendency being to make small slabs rather than cubes. Mainly for this reason the contractor has found it, under the terms of the contract, to be for his interest to crush the stone rather smaller than the specifications demanded and the quality of the road is thereby improved.

Notwithstanding, however, the poor condition of the first section as it stands at the present time, it seems to me to have been proved that the method is at the worst a great improvement upon the gravel road, for with the heavy traffic (carts loaded with crushed stone going down hill and drays carrying all the building stone that four horses could draw going up) which this road had during the past six months, I do not think a gravel road would have been much better than a quagmire.

In this case, as in all side hill roads when the ground is at all springy, we laid a tile drain four feet deep at the upper side of the road close under the bank and we have a steady flow through the pipes. Without such drains it does not seem as if any road could have been at all passable.

A word as to another feature of this work. One of the most annoying facts in macadamized and gravel roads which have sewers under them, is the constant appearance of manhole covers above the surface. Horses shy at the round, black spots, and carriages are wofully racked by the sudden blow of passing over them. Now, on Corey Hill we have both surface water drains, averaging, perhaps, seven feet deep, and sewers averaging about twelve feet, and in order to rid the road of the manhole nuisance as far as possible, we have laid the two lines of pipes in the same trench,

making a manhole with two water-tables, one seven feet and one twelve feet below the surface. The upper pipe is laid on a berm carefully made and the two pipes are three feet apart on centres horizontally.

The above method promises well in this case, where the material is very hard, and one set of manholes is saved. The manhole is much more convenient for inspection than the ordinary form, and costs something less than two single ones.

The great question is whether the berm on which the upper pipe rests may not become softened and allow the pipe to settle. A trench which has been dug and refilled almost inevitably allows more or less surface water to pass through the replaced material, and it is possible that this might result in impairing the solidity of the berm; but as great care was taken to insure thorough ramming in back-filling, we do not expect trouble. Of course this berm must be below frost or trouble would assuredly result. Whether such a plan would answer in sand or gravel, I am in doubt, for the difficulty of excavating for the lower pipe without distributing the solidity of the material upon which the upper was to be laid, would be considerably increased. Sheeting the deeper trench and leaving the sheeting in would assist, of course, but the expense would be scarcely warranted by the results obtained.

The subject of back-filling brings to mind what has always seemed to me one of the reasons why so many of our streets are unsatisfactory with respect to smoothness and evenness of wear,—lack of thoroughness in replacing material which has been excavated for the purpose of laying pipes. Puddling with large quantities of water does not seem entirely satisfactory, and thorough ramming in layers, which comes nearer reaching the desired end, is expensive, although on the whole I believe it to be more economical in the end than partial work. A combination of the two methods would perhaps give the best results at not very greatly increased cost over the puddling. Back-filling in layers not over eighteen inches thick and *dampening* the earth with a hose while ramming as thoroughly as possible with so thick a stratum ought, it seems, to thoroughly compact the material.

The amount of crown to be given to the surface of the road is a question always vexing. As a general rule I think we allow four per cent. slope from the centre to the top of the gutters—more than that in steep grades, and less, though not much less, in flat. The construction of the road in other respects has so strong a bearing upon this important detail, that to set any fixed slope would be unsafe. A gravel road requires more crown than a macadam road, and earth needs more than either.

With respect to the use of binding material, such as clay or gravel, for the surface, circumstances vary so widely as to prevent any fixed rule. In my opinion it all depends upon the comparative hardness of the stone and the gravel. I formerly thought that stone alone should be used for the work throughout, and that like the Irishman's idea of putting water in a punch—every drop spoiled the punch—every shovelful of gravel was a direct injury to the road.

In some places, however, a gravel is found which wears long and well, while the stone obtainable in that region is only fit for the foundation. For instance in Stockbridge and Lenox in this State, most of the stone to be obtained is a rather soft limestone which soon makes dust (or mud in wet weather), while they have there what is called—I do not know how correctly—*flint* gravel which wears extremely well and makes a handsome surface, although it packs with difficulty if more than three or four inches deep.

In the construction of Beacon street, some experiments were tried upon the use of hardpan, gravel, etc., as materials for binding the surface, but we were soon satisfied that stone was the best material that could be used. The use of the stone screenings in this case was the most economical, as we had to pay extra for even the rather poor quality of gravel we are able to obtain.

The name of Lenox recalls a road which I saw building there last summer and which was a warning to me as to *over*-rolling macadam and the need of water. This road was built of crushed white marble, or what looked like that, and for dazzling whiteness exceeded anything I ever saw. It was rolled, however, with a fifteen-ton steam roller until all the upper half inch was crushed to powder and the limestone dust (no water was used so far as could be seen) was choking and irritating in the extreme. It is sometimes a nice question when a road has been rolled enough, and it is a point which the man on the roller, paid by the day, will seldom decide correctly, or disinterestedly. If some rolling is good, more rolling is better, is a dangerous precept to follow.

In the use of the steam roller as I have intimated, I am a firm believer. Most certainly for efficiency and economy it was of great value in the construction of Beacon street. It was found there, however, that the steam roller was rather apt to make waves in the road, especially if the crushed stone was more than four or five inches deep. Rolling with horse rollers at first and then with the engine was found to give a more satisfactory surface than by either alone. Another difficulty experienced with the steam roller on Beacon street was the crushing of the gutters out of shape. The heavy rear wheels, if allowed to run very near, or upon the gutter stones, would crush the gutter out of shape and sometimes destroy it altogether. Notwithstanding this difficulty, which to a large extent was avoided by ordering the steam roller away from the gutters altogether, it was found better to build the gutters first and lay the macadam afterward. If the macadam were laid first and rolled, the edges next the gutters were broken down and forced out so as to destroy a good deal of labor. The gutters were of cobblestone—the very poorest there is in my judgment. The beach stones called "kidney stones" make a very pretty gutter for private driveways and other roads where the traffic is light, but it is impossibe, I believe, to make a good, permanent gutter for hard use of rounded stone. Granite blocks are in the end much more economical, although even these leave much to be desired. The difficulty lies in making a good joint between two such dissimilar classes of work as macadam and paving.

Mr. McClintock's plan for training highway superintendents is ingen-

ious, and the idea of having competent engineering advice and following it, is certainly one which every member of the profession should exert himself to impress upon the public at large. But Mr. McClintock begins with the wrong pupil. In the first place, the public must be taught the desirability and economy of good roads and further to raise its voice in such unmistakable tones as to compel the city and town fathers to heed the demand for improvement. Then the same guardians of the public weal must have it drummed into their heads that although a man may be a good farmer and even perhaps able to get the most work for a day's pay out of a gang of voters, he may be and probably is, unless an engineer, profoundly innocent of any knowledge of how to build or maintain a good road. The most difficult part is the first perhaps, but it is no small undertaking to teach the average selectman or even a member of one of those august bodies, the county commissioners, that any special technical skill is necessary for the proper location, construction or maintenance of a road. "Every farmer knows how to build a road that is good enough and it will not cost half as much as one that an engineer plans, besides which you have to pay an engineer *five dollars* a day," is the answer one will meet in nine cases out of ten.

When towns in Massachusetts are found willing to risk the expenditure of fifty thousand dollars in the construction of water works with the combined engineering advice of a country lawyer and a hotel keeper, or seventy thousand for sewers upon plans drawn by a fire insurance agent, is it to be wondered that the people generally scorn the idea of having a man trained and experienced in such work plan and manage their highways.

While in ninety-five per cent. of the towns money enough is wasted every year, through bad designs and maintenance of their highways, to pay three times over for all the good engineering advice necessary to give them roads which can be safely traveled throughout the year, the almost utter impossibility of making the people understand the value of special technical knowledge bars the way to much improvement.

MR. J. EDWIN JONES:*—I think the Providence rule quoted by Prof. Allen for the cross-section of macadamized roads,—"½in. to the foot on level grades and increasing this as the grade increases to as high as one inch to the foot,"—is excessive, tending to throw all the travel to the center of the street and thereby forming tracks which retain the water; with a flatter cross-section all portions of the street are comfortable for vehicles and the roadway is more evenly worn. Smoothness of surface is far more important than extreme convexity, and unless this is maintained the wheel tracks will soon form channels along which the water will find its way, to the great damage of the street. Three eighths of an inch to the foot or one in thirty-two on macadam and one-fourth inch to the foot or one in forty-eight on paved streets is my rule.

I fully agree with Mr. McClintock in his practice of using as little binding material (stone dust or screened gravel) on the surface of the

* Contributed since the meeting.

macadam as possible; if the surface is rolled with the steam roller until the outline of each individual stone stands out clear and distinct, the whole presenting the appearance of a Mosaic, and so hard that no impression is made by the wheels of a passing vehicle, you may then put on a half inch of fine screenings from the crusher and your completed surface under the horses' feet will have the ring of the true metal. It is impossible to obtain this result with horse rollers, and gravel or other material must be used to assist in the consolidation of the stone. There is a general agreement as to the methods to be pursued in the construction of a macadam or a Telford-Macadam road; given the necessary funds and the engineer will solve the problem with ease, but there remains another and equally vital problem in the solution of which an opportunity is offered for some member of the Boston Society of Civil Engineers to write his name high among the benefactors of his race. The curse of our pavements to-day is not poor work or faulty construction; the street opening fiend is the source of all our woes. My friend Howe has described to us his methods of construction and maintenance of the admirable drives in the Back Bay Fens and the Franklin Park which after the wear of a year or more show no appreciable deviation from their original perfect contour. What would be the condition of that surface a year hence if within a width of thirty-four feeet, four longitudinal trenches should be cut the entire length and fifty miscellaneous openings for house connections within a distance of a thousand feet. An extreme case perhaps, but an actual recent occurrenee in Boston.

We live in a changing and we hope a progressive age; the five story building gives way to that of ten or fifteen stories, electric lighting is supplanting or supplementing gas, the telephone conduit must be in every street, and with it all comes the imperative demand, "let us into your streets;" there is no alternative but to comply with the demand, and twelve thousand permits, aggregating one hundred miles of trench, were issued in Boston last year. Under these somewhat depressing conditions would the Boston Society recommend the construction of a first-class block pavement upon a hydraulic cement base at a high cost without a guarantee that it should remain intact for at least five years? Would it recommend the substitution of sheet asphalt for macadam upon our Back Bay and other residence streets without a similar guarantee? I think not; there is one recommendation I think it would make, however, and that is the adoption of the custom in most European cities where permission is never given to private companies or persons to cut through the pavement in any street for any purpose. When such work is necessary the corporations do it in their own thorough way, and the interested parties pay the entire cost. An ordinance corresponding to this would undoubtedly be an excellent thing for any American city to adopt.

MR. GEORGE A. KIMBALL.*—The writer as a member of the City Council in a city of 40,000 inhabitants, a suburb of Boston—was placed by the Mayor at the head of the Committee on Highways having in charge the

* Contributed since the meeting.

construction and maintenance of the streets and gives herein a statement of the workings of the department and the cost of some of the work.

The city is governed by a City Council consisting of a Mayor, Board of Aldermen of eight members, and a Common Council of sixteen members All are elected annually for one year, the Mayor and Aldermen by the votes of the whole city, the Common Council by their respective wards.

The Mayor is the chief executive officer, and appoints certain officers; it is his duty to see that the laws are enforced, to keep a general supervision over all subordinate officers, he presides at the meetings of the Board of Aldermen and has a veto power over all votes contemplating the expenditure of money.

The Board of Aldermen have power under the statutes to lay sewers and build sidewalks but the money therefor must be appropriated by the City Council. The City Council is authorized to lay out streets and appropriate money therefor.

The Committee on Highways is appointed annually consisting of two alderman and three councilman who are appointed by their respective presiding officers. To this committee all matters in relation to street are referred. This committee is also expected to look after the construction and maintenance of streets and sidewalks in the city and to have general charge of all matters relating to streets.

A Superintendent of streets is elected annually by the City Council. He receives a salary of $1,500 per year, he selects his own assistants, employs all labor and has general charge of the construction and maintenance of all streets and sidewalks acting under the direction of the Committee on Highways.

It is the custom of the City Council to annually appropriate a sum of money for the construction of new streets, repairs of streets and sidewalks and a further sum for construction of sidewalks.

New streets are laid out by the City Council, they must be at least 40 feet wide, and they are usually brought to a proper grade by the abbuttors. When a petition is presented for the acceptance of a street the abbuttors are required to file a plan and profile of the same showing the abbutting lands with the fences and buildings thereon, frontage of each estate, lands to be taken, names of owners, grade proposed, and such substantial bonds or references as may be necessary to determine the lines, also an agreement signed by all the parties releasing the city from all damages or stating the amount they will accept in payment of damages. The streets are usually graded by the abbuttors, then they are accepted by the city without assessing the abbutting estates. In cases where it is necessary to take private lands at considerable expense, or where the construction is entirely by the city, a portion of the expense is assessed on the estates benefitted.

In 1890 the city contained 85.86 miles of public or accepted streets and 34.5 miles of private streets including courts, places, etc. The appropriations for the year for building new streets and the maintenance of streets and sidewalks was $46,000, for building new sidewalks $10,000, as one-half the cost of the sidewalks are assessed on abbutting estates double the appropriation or $20.000 was available for new sidewalks.

At present the city performs all work on the streets by day labor and is the owner of the following plant.

Stone Crusher and Engine.

Harrisburg Steam Road Roller, 15 tons.

Iron sectional roller for two horses.

Granite roller for five horses.

Granite roller for two horses.

Champion Road Scraper.

One street sweeper.

Ten snow-plows for clearing sidewalks.

Four gutter plows.

Twenty-three horses.

Five double carts.

Ten single carts.

Also many other small tools and implements the whole valued at $10,792.

Crushed Stone.

The stone crusher is a Marsden & Farwell, 9×15 in. It is set at the quarry, and is provided with an elevator and elevated storage bins, of two hundred tons capacity. The crusher is set on an elevation, and in reaching it with the stone from the quarry it is necessary to ascend a steep grade, which increases the cost of delivering stone to the crusher.

The cost of crushing under the present plan, including the quarrying and teaming to the crusher, is $0.65 per cubic yard.

The stone is quarried with less expense than in most cities, and is not so well adapted to good roads as a harder stone.

The city purchased crushed stone, delivered on cars at Fitchburg railroad, for $1.65 per cubic yard, one yard weighing 2775 lbs., which would be $1.20 per ton; also purchased for $1.30 per ton delivered on the Boston & Maine railroad.

Repairing McAdam Roads.

There are no paved streets in the city. The streets are generally macadamized, and those on which there is a heavy travel require frequent repairs.

The method of re-macadmizing one of these streets during the past season was as follows: All the dirt was carefully removed, the uneven places smoothed, and crushed stone was applied—without picking up the original street surface—to a depth of six inches at center and two inches at the gutters. The stone was thoroughly wet and rolled, then covered with a thin coating of fine gravel and wet and rolled, all the rolling was done with a 15 ton steam roller. The cost of the work was $0.43 per square yard.

Sidewalks.

Sidewalks are laid as per orders from the Board of Aldermen, under Chap. 50 of the Public Statutes. One half the cost is assessed on the abutting estates, the remainder is paid by the city. If a short length of walk is called for, as in front of one or two estates, the city performs all the labor, the owner of the estate agreeing, in writing, to pay for the brick and curb required.

The cost of a sidewalk 6 ft. 8 in. wide, with curbstone and covered with gravel, not including gutter, was from $0.90 to $0.70 per lin. foot. The cost of the curb, delivered on the street, was $0.44 per lin. foot. The cost of the brick paving on sidewalk was from $0.90 to $1.00 per square yard. Price paid for brick delivered. $13 and $13.50 per thousand. When the curbstone is set the gutter is laid, usually with cobble paving, at a width of three feet—sometimes four feet on steep slopes—the cost of which is from $0.90 to $1.20 per sq. yard. The price paid for cobble paving stone delivered on wharf was $1.65 per ton. Sidewalks of gravel or earth, without curbs, are built when necessary, and no assessment is made on abutting property.

Crossings.

Street crossings are constructed when ordered by the Committee on Highways. They consist of one or two rows of granite flagging two feet wide, with paving three feet wide on each side. The cost was as follows:

Crossings with one row of flagging and paved each side with granite blocks....................	$2.00 per lin. ft.
Crossings with two rows of granite flagging, paved between with three rows of granite blocks and outside with cobble paving	2.65 " " "
Crossings with two rows of flagging and all paved with granite blocks.......................................	2.75 " " "
Crossings with one row of flagging with cobble paving	1.50 " " "

Curbstone and Paving Stock.

Specifications:

Paving Blocks to be of the best Cape Ann or Quincy Granite, and all other granite to be equal in quality thereto.

Curbstones to be of granite, out of wind, 7 inches wide on top, not less than 6 feet in length, or less than 18 inches in depth, with horizontal beds not less than 10 inches in width, to be hammered on top and 2 inches on back, to be rough-pointed on face to a depth of 8 inches, and the ends to be squared with the top and jointed.

Granite Flagging for street crossings to be 2 feet wide, from 3 to 5 feet long, and not less than 7 inches deep, hammered to an even surface on top and jointed on sides and ends.

Circles to be of granite, 7 inches wide on top, not less than twenty inches in depth, or less than 4 feet in length, with horizontal beds not less than 10 inches in width, to be rough-pointed on the face to a depth of 8 inches, and to be neatly cut to a radius of 6, 8 or 10 feet, as the superintendent of streets may require.

Corners to be of granite, neatly cut, not less than 18 inches in depth, to be rough-pointed on face to a depth of 8 inches, and to be 3 or 5 feet in length, as the superintendent of streets may require.

Paving Blocks to be 3½ to 4 inches wide, 6 to 8 inches long, and 7½ to 8 inches deep; all edges to be sharp and straight, and to be at right angles at intersections, both horizontally and vertically; faces to be free from bunches and depressions; to be equal in quality and finish to the best Boston block, and to sample on exhibition at this office.

All the above named materials to be delivered at such times, and in such quantities, and upon such streets as may be designated by the superintendent of streets, and to be satisfactory to him and to the committee on highways in every respect; all rejected materials to be removed at once by the contractor.

Prices paid in 1890, all material being delivered on ground as ordered:

Curbstones, per lin. foot	$0.44
Granite Flagging, per sq. foot	0.35
Circles, per lin. foot	0.65
Corners, three feet, each,	2.00
Corners, five feet, each,	2.90
Paving Blocks, best Boston, per thousand	39.50
" " second quality per thousand	26.00

For cobble paving delivered on wharf, $1.65 per ton.

The foregoing is not given to the members of the society as a model for the management of the street department, but is simply the record of the actual doings of the department in Somerville for the year 1890.

The writer believes that all public works should be managed by a board of public works, consisting of the heads of the several departments, and a majority of this board should, in all cases, be composed of civil engineers.

The trouble with the present system, in the most of the cities, is the constant changing of the board that has these matters in charge, which prevents the carrying out of systematic construction, and also of the proper maintenance required in all public works.

Too much cannot be said in regard to the importance of a thorough and systematic maintenance of macadamized streets.

"Eternal vigilance is the price of safety," is a proverb that applies to street work, and should be strictly followed in all cases.

The most successful road builders are those who have built and also maintained their roads; and their success has been due as much to their vigilance in maintenance than to their skill in construction.

CONSTRUCTION AND OPERATION OF CABLE AND ELECTRIC RAILWAYS.

DISCUSSION.

(*Continued from page 94.*)

WM. H. BRYAN.

In the discusssion of December 17th, Col. Meier presented some data on the cost of power on cable and electric roads. The unfavorable results shown by one of the electric roads were attributed by the speaker largely to the fact that high speed engines belted direct were used—the inference being that if large slow speed engines with countershafting had been employed, the cost of the power would have been greatly reduced. I have not been able to secure any data bearing directly on this point, but there

is much to be said in favor of the opposite view. Two years ago in a paper read before this club, I discussed this subject at some length. The conclusion which I reached then was, that for approximately constant loads, the large engines with shafting were preferable, but where the work varied largely, the high speed engines belted direct would be found more economical. I have taken every opportunity since then to study the question further and can see no reason for changing my view. The unfavorable results cited by Col. Meier, could, I think, be traced to other causes. The largest builders of electric roads have not yet reached a conclusion—one of them prefering large low speed engines with shafting and the other high speed engines. The practice of the latter company is based on experience gained in operating large incandescent electric light plants, where the load is subject to wide fluctuations, though not as sudden or severe of course as in railway work.

Compound high speed engines are, under similar conditions, at least as economical as the single cylinder Corliss engines, generally used. If however, we compare the latter with single cylinder high speed engines, the Corliss engines will probably show a saving of 15 to 20 per cent. in fuel. The large countershaft required with the low speed engines consumes a constant horse power—varying from about 10 per cent. of the maximum load, and 15 to 25 per cent. of the average load—up to as much, or more than the useful output under light loads. It would appear, therefore, that the superior economy of the low speed engine is almost fully balanced by the excess of power lost in driving the shafting. A further advantage is that during those hours when the load is light, several of the small engines may be shut down, leaving the remaining engines to run at more economical points of cut off. The large engine; however, must run all the time together with most, if not all of the shafting. Under light loads. therefore, the large engine will cut off at a very early point in spite of the excessive dead load. while the smaller high speed engines would do only useful work, and under conditions far more favorable to economy. It would seem, therefore, that the net fuel economy for a whole day's run would be in favor of the high speed engines.

Closeness of regulation seems also to be in their favor. I was told yesterday that the variations in speed in a certain low speed station in this city are three times as much as in a corresponding high speed plant here. This is as might be expected for the changes of load are felt directly by the governor instead of having to be transmitted through the heavy shafting; besides which the engine itself has more than three times as many opportunities to adjust its speed in the same time.

The high speed permits the plant to be installed for the least first cost, and to occupy the least space. The necessary reserve engine also requires a much smaller investment of idle capital and space. These items affect the fixed charges seriously. An accident to one of the large engines is a serious matter, as it means a large reduction in the capacity of the station, while one of the smaller high speed engines could be spared almost without being missed, it being so small a part of the total capacity.

Electric railways have an advantage over cable lines in that the power

station may be located at some distance from the line, thus getting the benefit of cheaper land, switching facilities for coal and ashes, cheap water—and sometimes water power. The cost of increased length of circuits, cost of maintenance, and losses due to leakage, drop, etc., must all be taken into consideration in determining how far away it will pay to go.

Prof. Nipher.

This discussion seems to me to be like an attempt to determine whether it costs more to support the family of a lawyer than a physician, by an exhibit of the family bills of a dozen cases, selected by the champions of the two sides for the purpose of making a case.

I do not know of another industry that has grown in so short a time to such tremendous proportions, as the electric railway business has assumed in the last two years. It is certainly proper for those who oppose the system to work with diligence. The rapid growth has, however, brought some disadvantage. The manufacturing companies have not only been pushed to the utmost to fill orders, but they cannot find the men to properly install the plants they sell. It has, therefore, happened that men who might perhaps succeed in building a telegraph line, are sent to install a railway plant. The steam engine part of the plant has been given into the hands of some one who had an engine for sale.

Nothing has surprised me more than the large slow-speed engines and immense countershafts with which some of our power stations are adorned. To establish such a plant is to ignore the accumulated experience of ten years.

In the first place the countershaft at once wipes out the gain in efficiency which a large engine is supposed to yield. It is again wiped out by uneconomical operation of the engine during the hours of light load.

Again, a large engine takes no notice of the distress of a single overloaded dynamo. It is more difficult to make individual dynamos carry their proper share of the load. As is well known, when dynamos are working in parallel, if the potential of one falls three or four per cent it ceases to act as a generator, and may even be driven as a motor. If it were a plain shunt dynamo, it would aid in driving the countershaft, but the other machines acting as generators would be overloaded, and a great loss of energy would be the result. The situation is then, that only part of the generators are sending current to the line, and they are dividing their current between the line and the dynamos which they are operating as motors.

But in the operation of a railroad, where great and sudden changes in load may occur, a compound dynamo might and probably does reverse and work against the engine in such a case. This is due to the self induction in the shunt coil, which causes the series coil to act first in case of a lagging dynamo.

Such experience has long ago been met in electric lighting, and the way of providing against it is well known. When the Edison central station was started in New York, they had separately driven dynamos. The engines used were in good standing, but they were finally thrown out because they were not well enough governed. Another engine was substituted, and it succeeded, and was given a great reputation as a well gov-

erned engine. It is now known that the first engine failed because it was a well-governed engine. If one or two dynamos began to carry the rest of the plant as well as the lights, the engines maintained their speed until something gave way and the lights went out. The second engine placed under the same circumstances, slowed down and shifted an equitable share of its surplus load to the lagging dynamos.

In a cable system, if a load is suddenly thrown on, the shock on the engine is cushioned by the lifting of slack cable along the line. In an electric system, the change is instantly felt in the power house. The moving masses in the power house of an electric railway should be small, and the engines should be high speed engines not too well governed. To build an electric power plant in imitation of a cable plant, is to abandon some of the main advantages of an electric system. Such plants, however, serve to aid us somewhat in the practical solution of a somewhat famous mechanical conundrum which interested men in a former age more than it does now,—what will happen if a body moving with resistless energy, collides with a body which cannot yield?

There are plenty of electric roads which are being operated in a most satisfactory way. We hear nothing of them. We need go no further than Kansas City to see a most impressive case, where five miles of electric road and five miles of cable road are being operated from the same station. They have the same number of cars, and the cars are worked to their full capacity. A mere inspection of those two plants will satisfy any person that a properly installed electric plant needs no defender when compared with a cable plant. When an electric road behaves like those of which we have heard to-night, you may be certain that there has been a mistake somewhere. And it takes time to educate the employes of an electric road. They now destroy a great deal of machinery, because like most people, they cannot learn from the experience of others, and cannot think quickly in new emergencies. Our cable friends should be patient, for there is every evidence that the electric road is here to stay.

IN MEMORIAM—SAMUEL F. BURNET.

A MEMOIR BY S. BENT RUSSELL, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

The welfare of our profession has one of the foremost places in our hearts, and to promote it is one of the main objects we engineers have in organizing such societies as this, our Engineers' Club.

There are many ways in which our united action may help to elevate our profession and one of the most important of these is that of aiding and appreciating individual effort among our members. Both individually and collectively we can do much towards the success of our brotherhood by doing all in our power to assist the younger members who are deserving and worthy of our help, and further, by giving all honor to those who, by their untiring efforts and unswerving fidelity, have earned the confidence of their employers and associates and attained success as engineers.

We are commanded to *judge not*, but we are also told to *give honor to whom honor is due.*

Let us give honor to our deserving brother, and let us give all honor to one who has received his honorable discharge from a higher power.

Let us have our own Westminister Abbey between the covers of our proceedings, where the names of our honored dead shall remain undisturbed as long as our profession shall exist and the English language be read.

Samuel Forder Burnet was born in St. Louis County, Missouri, November 10, 1860. Entering the Freshman class of Washington University, St. Louis, in 1877, he completed the course in the required four years, and in June, 1881, received the degree of Engineer of Mines. He was following in the footsteps of his two elder brothers who had adopted engineering as a profession.

As a student he was conscientious. His work was always thorough and, to my recollection, of about equal strength in all branches of study essayed by him. If he had any preferences they were for shop work at the forge, lathe and bench, and for instrument work in the field.

In athletics he was ever among the foremost.

The youngest of his class it is notable that he was afterwards among the first of them to take a wife and the first to leave us for eternity.

His first work was done while still a student, in the Summer of 1879, when he was engaged with an engineer corps on the construction of the Indianapolis, Decatur & Springfield R. R.

After taking his degree he was employed with a corps of the Mo. Pac. Ry., surveying a location from Tower Grove Station, St. Louis, to Carondelet. In the Autumn he joined a corps on railway construction for the Toledo, Cincinnati & St. Louis R. R. Co., and had charge of and completed the construction of a 20 mile section.

In March, 1882, he entered the department of the Water Commissioner of the city of St Louis, and was for several years engaged as assistant engineer on the construction of high service pumping station No. 2, which was a case largely of difficult foundations; and later of Stand Pipe No. 2, which is now such a conspicuous landmark in the northern part of our city, and in the erection of which any one might be proud to have taken part.

It was while engaged on this work that on Nov. 10, 1885, he married Miss Rose Andrews, of St. Louis.

He had personal charge of an important topographical survey of the Northeastern part of St. Louis County. This survey mas made to aid in the study of the feasibility of taking the city's water supply from the Missouri River. Later on he had direct charge of the construction of the inclined tracks on which travel the four pumping engines of 5,000,000 gallons daily capacity each, which are known as the pumps of the temporary low service station.

In 1888 Mr. Burnet was appointed Second Assistant Engineer on the Water Works Extension. This sub-department was organized for the purpose of making surveys and designing and constructing a new low service or supply station at the Chain of Rocks about seven miles above the present intake, together with a new system of settling basins at the same point and a masonry conduit or aqueduct to conduct the water by gravity to the present high service pumping stations.

Under the Water Commissioner the sub-department is in charge of the Principal Assistant Engineer. Under the latter the work was subdivided into four divisions, viz: The River Division, the Settling Basin Division, the Conduit Division and the Drafting Division.

Soon after his appointment Mr. Burnet was offered the choice of the River and Conduit Divisions. He chose the River Division as promising the more difficult problems and more interesting work. This division included the river or Inlet Tower, the inlet tunnel and the engine and engine house foundations and appurtenances.

The Inlet Tower is of masonry and rests on a solid rock ledge 1,500 ft. from shore and twelve feet below low water.

The inlet tunnel is driven through the solid rock under the river and is connected to the tower at the outer end by a vertical shaft, and to the wet well, from which the pumping engines draw, at the shore end. About 1,500 feet of this tunnel lies under the Mississippi.

Mr. Burnet was first engaged in making preliminary surveys and soundings for the proposed works. Later he commenced the sinking of the shaft at the shore end of the tunnel from which the tunnel is now being constructed. As the nature of the work and extent of it were considered uncertain, Mr. Burnet was instructed to sink the shaft by day labor with such help as could be obtained.

Considerable difficulties were encountered in sinking the first thirty feet in depth through earth and quicksand, and the water encountered at the surface of the rock offered serious problems before it could be shut off and blasting begun.

After that the shaft progressed at a fair rate until a wet seam was reached at a depth of about 75 feet.

When the sinking reached a depth of about 90 feet, work was discontinued and contracts let for the tunnel and tower.

The lines and grades were given and the heading commenced under Mr. Burnet's direction, and he was engaged on this work up to the time when his ill health compelled him to withdraw, for recuperation, as everyone thought, but as it turned out, to give up the work at last.

His ill health began to trouble him about a year before his death, but he was able to keep up with his work until the latter part of the summer of 1890.

He became a member of this club January 7, 1885. On March 21, 1888, he contributed a paper to our transactions on the "Selection, Inspection and Use of Cement and Mortar," which was published in our Journal for July, 1888.

Latterly he has contributed considerable matter to the collections of our club's local data committee.

He made no enemies and leaves many friends. When a student and when an engineer with all his associates he was a favorite.

In his practice he showed a special fondness for work in the field and a leaning toward the practical side of things.

Socially his tastes were quiet and domestic.

On the 11th day of February, 1891, he died at the age of 30 years, leaving a young widow and two little sons to learn to live without him.

The Assistant Engineer in any undertaking has usually the doing of the severe routine work, on the carefulness and accuracy of which everything depends. Here the avenues to fame are few and long. The full realization of long looked for results and the glory of success are not published to the world at large nor even to those who do and will benefit by them. They are known best to the few who are his intimate associates, and it is as one of these that I add this testimony to the record.

Such, briefly, was the life of Samuel Forder Burnet—an earnest and conscientious worker, whose achievements, while perhaps not so brilliant nor so widely known as those of others gone before—were yet creditable and enduring—testifying to future generations of duty well performed.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

Annual Dinner.

The ninth annual dinner of the Boston Society of Civil Engineers was served at Young's Hotel, Boston, Tuesday, March 10, 1891.

An informal reception was held at 5 o'clock and at 6 o'clock members and guests to the number of 127 sat down to dinner.

President Clemens Herschel presided and the following were present as guests of the Society:—Prof. N. S. Shaler, of Harvard University; Prof. A. E. Dolbear, of Tuft's College; Mr. F. E. Prindle, Civil Engineer, U. S. Navy; Hon. S. B. Stebbins, Chairman, New Court House Commissioners; and Mr. E. P. Dawley, Chief Engineer, N. Y. P. & B. R. R.

President Herschel, after extending a cordial welcome on behalf of the Society and reading letters of regrets from guests unable to be present, introduced as the first speaker Prof. Shaler, who spoke on the new map of the State of Massachusetts just issued *

Prof. A. E. Dolbear, the noted electrician and professor of physics at Tufts College, was the next speaker, and after some preliminary remarks said that the possibilities of electrical developements of which the signs were clearly defined were scarcely less marvelous and wonderful than the achievements of the past few years.

That in the great problem of operating our common railways with electricity as a motive force, the science was already sufficiently advanced, that it was merely the practical application in which the details remained to be developed.

That there was to-day the best scientific grounds for believing that an electrical railroad for moderate distances, as for instance from Boston to Lowell could be constructed and operated with an economy equalling that now secured by the use of steam.

In speed the steam railroad has reached its limit; not so the electric railway, and Prof. Wahl, of Philadelphia, was referred to as having said that he would stake his reputation as an engineer that an electric railroad on which the trip from New York to Philadelphia could be compassed in a single hour, was entirely tenable as a scientific possibility. That it merely required the courage of capital to accomplish it.

He called on his hearers to remember that three years ago there was not in existence an electric road, as we understand the term to-day anywhere in operation, but that when once a company of New York capitalists had the courage of their convictions and built the road at Richmond, the development of other lines throughout the country followed with a rapidity such as to almost exceed the wildest dreams of a year before.

Prof. Dolbear also referred to the marvelous possibiilties of what is known as the "Porte-electric" system. That here too, it was merely some of the practical details that had to be studied out and over-come, and stated that he was familiar with what had been done in this line and was wholly convinced of the good scientific foundation on which the system rested and that already at Dorchester, on the experimental line, a car weighing some 500 lbs., was forced along a three-quarter mile circuit with a speed of from some 40 to 50 feet per second, even on a roughly

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*An abstract of Prof. Shaler's remarks will be found in the June number of the *Journal* in connection with a discussion on the new map.

constructed track and that he himself believed it entirely among the possibilities to obtain a speed of two miles per minute in this manner. The system consists of a cigar shaped car propelled by electric attraction through a series of helices, each one energized by a current while the car is in it. He stated further that he did not apprehend the cost of this system at all prohibitive, but that from $15,000 to $20,000 per mile would construct a package line on this principle, which could easily take mail bags from Boston to New York in two hours. He viewed this system merely as a means for transporting packages and mail. That a passenger railway on this principle had not been seriously considered, for men would hardly consent to be cramped into the small compass necessary, or to be conveyed at such high speed.

Lieut. E. J. Spencer, late of the U. S. Engineer Corps, but now of the Thomson-Houston Electric Co., was the next speaker. He spoke first of the electric railroad and of the marvelous improvements in its motors that were even now accomplished facts, and said that the noise of the street car motor had been suppressed by the introduction of a slow speed motor abandonment of the intermediate gears, and submerging in oil the remaining pinion and gear.

Speaking of the great advantages arising from the application of the motors in the work of the navy, he said that the objectionable steam pipes running to all parts of the ship were replaced by slight cables, and compact motors afforded the means of handling guns and tackle of every kind.

He also spoke of the development of electrical transmission for hoisting purposes; and said there was already under consideration, or closed, contracts for operating cranes and hoisting tackle, and for unloading cargoes along the water front of New York Harbor involving a thousand horse-power, this much would be in use at the close of the present season.

Within the past month the preliminary steps had been taken toward the development of an electrical fire-pump. A pump of this sort capable of throwing 1,200 gallons per minute, would be ready for use early the present summer and could be operated by a wire led in from the central station or from the street car line, and thus be instantly available day or night without having to rely on a supply of steam in the boilers,

Electrical drilling machines are being put into operation daily, he stated, and within the past month contracts had been closed for 1,500 horse-power of electrical coal mining machinery.

As one more instance of the active development of the practical applications of electricity, he said that preparations were in active progress for equipping an elevated railroad similar to those of New York City, with cars operated wholly by electric motors, and thus entirely doing away with the locomotives.

The possibilities of the storage battery too, he concluded had recently been wonderfully enlarged. In its form, as known up to the present time, its possible limit of efficiency had been reached; but new developments indicated that its evolution of electricity could be made a by-product, as it were; while chemically valuable salts would be obtained as a result of the electro chemical action.

Prof. T. M. Drown of the Massachusetts Institute of Technology and Chemist of the State Board of Health, was the next speaker, and gave as his sentiment "The co-working of experts, the key to modern progress." That each man can do the best which he is capable of doing only in an extremely narrow field, and it is only by the co-working of men, each an expert in his particular line, toward a common end and in close consultation, that some of our best results were being achieved.

He spoke of the success with which the engineer and the chemist had worked together on the problems presented to the State Board of Health. One result of this co-operation being the development of the theory of the isochlors or lines of distribution of equal chlorine in natural waters. That in the sanitary study of water supplies, chlorine had come to be taken as an index of pollution, and that their investigations had developed the remarkable fact that the normal percentage of chlorine, differed greatly in different sections of the State, and that on plotting the normal percentage of chlorine found in pure natural waters, on a map of the State, it was found to steadily increase from the west toward the eastern border,—due doubtless to minute portions of salt water carried inland by the winds of our easterly storms; and that now knowing what amount of chlorine ought naturally to be

expected in a given locality, the percentage actually found, by its relation to the normal amount, enabled conclusions as to possible pollution to be drawn with a certainty never before reached.

Prof. H. M. Howe of the Institute of Technology and author of the recent notable work on the "Metallurgy of Steel," next spoke relative to the engineers tests and specifications for structural steel, and urged that more careful attention be given in the future to designing tests so as to reproduce the practical conditions of use, and to show to what degree the metal possessed the properties it was to be actually called on to display in practice

That it was absurd to do as had been almost wholly done in the past, and rely on static tensile tests where the metal was to be called on chiefly to resist shock, or compression, or abraison, its power to resist these, and not its behavior under static tensile stress, was under such conditions the true measure of its value.

He also deplored our scanty knowledge of the actual composition and treatment which best fitted steel even for many of its most important uses; the fittest composition and treatment were, as yet, largely matters of opinion rather than of knowledge. This was evidenced in that the most famous authority in the world on the proper qualifications for rail-steel held that it should be soft, while most other experts held that it should be hard.

Civil Engineer Prindle of the United States Navy was the next speaker and briefly alluded to the fact that although we had made a beginning toward putting our naval construction on a proper footing, it was only a fair beginning that had been made.

Prof. G. F. Swain of the Institute of Technology, who was called upon as the "superintendent of our local engineer factory," urged that engineers and the public should bear in mind that a school could not properly claim to turn out full-fledged engineers; that it was by the very natnre of the circumstances impossible that they could do so. An engineer becomes worthy the name, above all, through the possession of judgment, experience and knowledge.

It is impossible for the engineering school to give experience, except to a very small extent; the judgment it can cultivate, but this faculty must be inborn in the successful engineer; knowledge it can give together with a training of the mind that will enable the graduate to learn and study after he leaves the school, to think clearly, and to avoid fallacies into which an untrained intellect would be apt to be led.

He urged the engineers present to bear in mind that when they take the technical graduate into their emlpoy they must not expect that they were securing the services of an engineer, but of one who has had such a training that he ought soon to become an engineer.

The technical school must be looked upon as giving to the average man a training in the science of his profession, which he would nine times out of ten not otherwise acquire; it gives a short cut on the road toward becoming an engineer, which enabled a man who had pursued these studies to make much more rapid progress than as though he had not been so favored, and to think easily in directions which otherwise his mind would not he apt to take.

Mr. Hurd Peters, City Engineer of St. John, New Brunswick, was called on as a representative from "a-way-down-East;" and after a most kind fraternal greeting on behalf of the Canadian Society of Civil Engineers, and assurance of a hospitable welcome to such of the members who might visit his city, referred among other things, briefly to the fact of the permanent character which it was possible to give timber structures in harbors in that vicinity, by reason of the entire absence of the *teredo*.

Past President FitzGerald was called on for some more of his experiences as a "Forty-niner" and gave some, but for his "facts" relied more on his imagination than on his memory.

Thomas Doane spoke of the early history of this Society.—That it was established in 1848 and was the earliest Engineers' Society in the country. That its membership though limited was of a very high class including such men as Mr. Francis, Mr. Chesbrough, Capt. Bennett, and others, but that by its somewbat exclusive policy at a day when engineers as a class were less numerous, the society

after a time languished and meetings became irregular or rare and some dozen years later a body of younger engineers had independenty formed a modest society of their own which gave such signs of life and progress that incorporators of the original society thought well to call a meeting and elect these younger men in a body into the older society, and with this infusion of young blood and the breaking down of undue exclusiveness a new and vigorous career was entered upon.

Other speakers followed, among whom were M. W. Oliver, who gave some reminiscences of the technical training available 40 or 50 years ago. F. P. Stearns, W. E. McClintock and Henry Manley also spoke briefly. The meeting then adjourned.

Annual Meeting. March 18, 1891.—The annual meeting of the Society was held at the American House, Hanover Street, Boston, at 19:45 o'clock. President Herschel in the chair. Sixty-six members and sixteen visitors present.

The Tellers of Election ask for instructions as to counting two ballots which had been received, one with the member's name stamped and the other with the name printed, on the back of the envelopes. On motion of Mr. Freeman the Tellers were instructed to receive and count both ballots.

The record of the last meeting was read and approved.

The Secretary submitted the annual report of the Board of Government, which was read and accepted.

The reports of the Secretary and of the Treasurer were read and accepted.

The Secretary submitted the reports of the committees on Weights and Measures, on Highway Bridges and on Excursions, which were severally read and accepted.

It was also voted to continue these committees and the Board of Government was authorized to select the membership of the same for the ensuing year.

Mr. McClintock, for the Committee on National Public Works, submitted a verbal report, which was acceped and the same committee continued.

Mr. Doane read the report of the Committee on Common Headquarters for Scientific Societies, which was accepted and the same committee continued.

The Librarian submitted a statement in relation to the library, in place of a report of the Committee on the Library. The statement was accepted and the committee continued.

Mr. Brooks made a verbal report for the Committee to confer with the Committee on Constitution of the American Society of Civil Engineers, which was accepted.

On motion of Mr. Smith, the Board of Government was authorized to print such of the reports or parts of the reports as it deemed advisable.

The Secretary read a communication from E. D. Meier, Secretary of the Eads Monument Association, enclosing a subscription blank to be used in securing contributions to the funds of that Association. The communication was placed on file and the Secretary requested to insert in the notices of the next meeting a call for subscriptions in aid of the Monument Fund.

President Herschel then delivered his annual address, entitled "On the Advancement of the Profession of the Civil Engineer."

Mr. Gould gave notice in writing of an amendment to by-law 6, substituting the words "two-hundred dollars" for "one hundred dollars" as the salary of the Secretary.

Mr. Howland, for the tellers, appointed to canvas the letter-ballots for officers, announced the result of the ballot. There being no choice for Director, the meeting proceeded to choose from the two candidates having the highest number of ballots. As the result of the letter-ballot and choice of the meeting the following were announced as the officers elected:

President, Frederic P. Stearns.

Vice-President, (for two years), William E. McClintock.

Secretary, S. Everett Tinkham.

Treasurer, Henry Manley.

Librarian, Frank W. Hodgdon.

Director (for two years), George F. Swain.

On Motion of Mr. Brooks, a vote of thanks was passed to the tellers, Messrs. Albert H. Howland and L. F. Cutter, for their faithful work.
(Adjourned.) S. E. TINKHAM, Secretary.

ANNUAL REPORT OF THE GOVERNMENT OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

In accordance with the requirements of the Constitution, the Board of Government submits the following as its report for the year ending March 18, 1891:

Your Treasurer's report shows a net gain of $601.01 to the funds of the Society, of which $462.62 has been added to the permanent fund.

At the last annual meeting our total membership was 237, four honorary and 233 active members. During the past year we have lost by death one, by resignations two and four names have been dropped from the list for non-payment of dues, making a total loss of seven. Thirty-five new members have been added to the list during the year, making our net gain 28. The membership of the Society at present is as follows: 260 members, 4 honorary members and 1 associate, a total of 265.

Eleven business meetings and one social gathering have been held during the year. At the business meetings the attendance has aggregated 525 members and 191 visitors, a total of 716. The smallest attendance at any meeting was 36, and the largest 92, the average being 65. The attendance at the annual dinner was 127.

During the year the following papers and discussions have been given at the several meetings:

March:—Raijan Canal and Irrigation in the Nile Valley, by Mr. Cope Whitehouse, of New York.

April: Special:—Transit in London, Rapid and Otherwise, by J. A. Tilden.

April:—Heating and Ventilation of Engineering Building, Institute of Technology, by Prof. S. H. Woodbridge.

May:—Terminal Facilities in Providence, by S. L. Minot.

Asylum Street Improvement at Hartford, by L. B. Bidwell.

June: Purification of Sewage by Filtration and by Chemical Precipitation, by Mr. H. F. Mills.

Sewage Disposal Works at Worcester, by C. A. Allen.

Chemical Treatment of Sewage at Winchester, by W. F. Learned

September:—Notes on English Mill Construction, by J. R. Freeman.

October:—Diagram for the Rapid Determination of sizes of Sewers, by E. S. Dorr.

Newton Water Works, by A. F. Noyes and H. D. Woods.

Settlement of Earth Embankments, by H. H. Carter.

November:—Roads and Roadmaking, by C. F. Allen, with discussions.

December:—Account of Work on Metropolitan System of Sewerage, by H. A. Carson.

Proposed Sewerage System for Washington, D. C., by F. P. Stearns.

January:—Navigation on the Upper Missouri River, by L. Bradford.

February:—Discussion on the New Map of the State of Massachusetts.

No progress has been made during the year towards securing permanent or more satisfactory rooms for the meetings of the Society. We cannot refrain from repeating our report of a year ago, that the present arrangement should not be considered as permanent or desirable. The impossibility of knowing which room will be assigned us until the hour has nearly arrived for calling the meeting to order, makes it very difficult to arrange properly any apparatus, plans or maps which it may be desired to exhibit. We also lose all opportunity for examining such books and pamphlets as may have been recently added to the library, which was found of value to many of our members at our former rooms.

It is again our sad duty to record the death of one of our members, Richard Fobes, of Worcester, Mass., who died February 5, 1891. Mr. Fobes joined the Society June 20, 1888.

Respectfully submitted on behalf of the Board of Government.

Boston, March 18, 1891. CLEMENS HERSCHEL, President.

Abstract of the Treasurer's and Secretary's Reports for the Financial Year 1890-91.

Current Funds.

Receipts.	
Dues of Resident Members for 1890-91, 175 at $6.00	$1050.00
" Non-resident Members for 1890-91, 52 at $4.00	208.00
" " " " "	1.25
" Resident Member for 1889-90	6.00
" New Members	138.00
Sales of Journals	13.40
Sale of Furniture	8.03
Repaid from Permanent Fund	11.88
Interest on Deposits	9.42
Cash at Beginning of Year	177.50
	$1623.48
Expenditures.	
Association of Engineering Societies for Journal	$633.14
Library, binding and periodicals	94.56
Printing, postage and stationery	300.89
Secretary's salary	100.00
Annual dinner	47.15
Stenographer	61.10
Expenses of meetings, rent and lantern	86.00
Moving furniture	5.00
Cash on deposit	295.64
	$1623.48

Permanent Fund.

Receipts.	
Thirty-five entrance fees	$350.00
Interest and dividends	144.75
	$494.75
Expenditures.	
Repaid current fund amount borrowed last year	$11.88
Cash on deposit	482.87
	$494.75

Schedule of Funds of the Society, March 10, 1891.

One Republican Valley R. R. Bond, par value	$600.00
Nine shares C. B. & Q. R. R., Stock par value	900.00
Mortgage on real estate	1500.00
Cash on deposit	778.15
	$3778.51
Schedule presented at last annual meeting	3177 50
Net Gain	$601.01

Report of the Librarian.

To the Boston Society of Civil Engineers:

The library has been located during the last year in room 70, American House. It is simply stored there in such a way that the books can be reached if wanted but there are no means for consulting them without taking them to the hotel reading room down one flight of stairs.

The current engineering periodicals which are taken by the Society have been bound and a part of the pamphlets received from the library of the late E. S. Philbrick have also been bound and placed on the shelves. As there is not room on the shelves for all the books a portion now has to be stored on the floor.

For the same reason and also on account of the limited time which the librarian has been able to devote to the library the most of the material presented to the Society during the year has not been placed in room 70, but remains in the office of the Secretary, who has kindly stored it until the librarian can find time to attend to it.

The "book club" arrangement of circulating the magazines taken by the Society has been discontinued owing to the difficulties encountered and the magazines are now received at, arranged and sent to the binders from the office of the librarian, as room 70 has not the necessary accommodations for doing the work.

The library, in order to be of value to the Society, should have larger quarters and more time devoted to its care than the present librarian can give to it.

Respectfully submitted,

Boston, March 18, 1891. FRANK W. HODGDON, Librarian.

REPORT OF COMMITTEE ON EXCURSIONS.

BOSTON, March 18, 1891

To the Boston Society of Civil Engineers:

The Committee on Excursions report that the Society have had eight excursions during the year with an average attendance of thirty-seven. They were as follows:

May 21, 1890:—Park System of Boston. 23 present.

June 17, 1890:—New Dam at Lake Cochituate, Framingham Sewerage Works, Worcester Sewerage Works. 65 present.

July 26, 1890:—Fort Warren, Boston Harbor. 47 present.

Sept. 13 to 16, 1890.—White Mountains (joint excursions with New England Water Works Association). 56 present.

Oct. 15, 1890:—New Reservoir and Filtering Conduit, Newton Water Works. 24 present.

Nov. 19, 1890:—Mass. Broken Stone Co.'s Works, Salem. 29 present.

Dec. 17, 1890:—Simpson's Dry Dock, East Boston (stormy). 9 present.

Feb. 18, 1891:—New Court House, Boston. 45 present.

GEORGE A. KIMBALL,
FRED. BROOKS,
FRANK O. WHITNEY,
CHAS. MILLS,
J. A. GOULD, Jr.,
Committee.

REPORT OF COMMITTEE ON PERMANENT QUARTERS.

BOSTON, March 18, 1891.

Your Committee on Professional Headquarters, though apparently inactive, has been considering this most important matter.

In order to complete its duties at this annual meeting and to lay before the Society the results of its endeavors and the opinion of the Committee, the Committee begs leave to make this its final report.

The Committee believes it not practicable to unite the various engineering and kindred societies in Boston, in the joint ownership of a building, and that, therefore, the Boston Society of Civil Engineers, now 43 years of age and supposably in the full vigor of its life, and with a membership of 265, should boldly go forward, either in its own name or by a majority of its members as stockholders, and secure proper and suitable headquarters.

The Committee, therefore, recommends that during the next six or eight months, an opportunity be given the members to take stock in this enterprise. The Committee believes that subscriptions can easily be had to $10,000 or $12,000 worth of stock, not however to exceed $15,000, with which to purchase a building suitable both as to location and fitness for its proposed uses.

A mortgage to the extent of from two to three times the amount of stock can be negotiated at from 4½ to 5 per cent. interest.

Thus premises costing $30,000 can no doubt be mortgaged at $20,000 or those costing $40,000 at about $30,000, or perhaps something less.

The civil engineers of Boston are quite used to expending large sums of other peoples' money, now let them show their confidence in the soundness of their own judgments by spending some of their own money, in such a laudable enterprise.

The Committee believes that after such a step is taken, or if it is found possible to take such a step, that its rooms can easily be let at remunerative rates to related societies, and that the stock can be made to pay fair dividends.

The Committee does not recommend that the Society, as such, undertake the work. The members will subscribe to stock in various amounts, according to their interests in the Society and to their means. Some may not feel able to take any. The control of the property must, therefore, be in the hands of the stockholders instead of the Society and the Society must lease its rooms and pay rent therefor, just as any other society may.

To bring this about the Committee recommends, that, next autumn, after a successful campaign, to secure stockholders and proper quarters, an application be made to the legislature, unless requisite authority be found under existing general laws, for a special charter for this purpose, which shall define the purpose of the corporation, fix the amount of capital stock and par value of the shares and define the method of organizing and officering the corporation.

The Committee suggests that the Society take early action, either in the way of approval or disapproval, upon the recommendations of this or some similar committee, that this work may *now* go forward or for the *present* be abandoned.

Respectfully,

THOMAS DOANE,
JAMES A. TILDEN,
FRED BROOKS,
ELIOT C. CLARKE,
HENRY MANLEY,
Committee.

REPORT OF COMMITTEE ON WEIGHTS AND MEASURES.

To the Boston Society of Civil Engineers:

Your Committee on Weights and Measures begs leave to say that the question of weights and measures is substantially in the same condition as it was at the time of the last report to the Society, and that your Committee is not prepared to make a formal report at this time.

It may be of interest to those members of the Society who are engaged upon topographical or geodetic work to know that the French Government is promoting the use of the centesimal division of the quadrant. It is claimed that "this division reduces the time from three to two, and the chances of error from four to one, both in observations and computations."

In order to increase the use of the centesimal division, the French Government has recently published a set of tables of logarithmic centesimal circular functions carried to five places of decimals, and has in preparation another such set of tables carried to eight places of decimals.

For the Committee,

Boston, March 18, 1891. CHARLES H. SWAN, Chairman.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

ANNUAL MEETING, MARCH 10, 1891:—The eleventh annual meeting was called to order at 8 o'clock by Vice-President Gobeille; 37 members and five visitors present. The minutes of the last meeting were read and approved. The Executive Board recommended the election of Mr. Frank Roy Lander to active membership. Mr. F. A. Coburn, for the Committee on Resolutions on the death of Mr. J. M. Blackburn, read the following:

Joseph M. Blackburn was born in Barnsley, Yorkshire, England, in the year 1822. He served an apprenticeship at the carpenter's trade there, and was employed as clerk of works and as foreman carpenter.

He was married to Miss Elizabeth A. Wells on January 1, 1845, and in 1851 they came to this country and to Cleveland.

He first carried on business here as contractor and architect, and after, as the evolution of the business of building here admitted, gave up contracting and gave his attention entirely to architecture.

Buildings of all descriptions in this city and throughout the State and in Pennsylvania and Illinois bear witness to his ability and industry.

His office has been the scene of the early labors of many of Cleveland's architects, who testify to his generous, genial ways, and to his devotion to his profession.

Mr. Blackburn was in poor health during the past year. He took a violent cold, and early in the month of February was obliged to confine himself to the house. His trouble culminated in emphysema of the lungs, and he died at 11 o'clock February 25, 1891.

Mr. Blackburn was an active, interested member of this club since the first regular meeting, April 3, 1880.

He was a member of the Euclid Avenue Baptist Church, having united therewith more than twenty-five years ago.

His wife died in July last. Of their six children five are now living.

The following is respectfully submitted by the Committee.

Resolved: That, in the death of Joseph M. Blackburn, we lose a faithful and respected brother and a useful, worthy, industrious citizen.

We shall miss, with sorrow, his cheerful, cordial presence among us.

FORREST A. COBURN,
AUG. MORDECAI,
Committee.

MR. MORDECAI:—I have known Mr. Blackburn for a number of years, and have always admired him for the simplicity of his character and his sterling worth. He was everywhere the same modest, true gentleman, and although not taking a very active part in the meetings of this club, still he had a very warm feeling for it. I move that the remarks and resolutions that have just been read be spread upon the minutes of the Club, and a copy be sent to his family.

MR. RICHARDSON:—I wish to confirm the remarks made by Mr. Mordecai. I met Mr. Blackburn a good many years ago, and found him a gentleman in every respect. Regarding the Club, whenever there was a banquet or tickets to be sold for a picnic or anything of that kind, he always responded cheerfully. He took a warm interest in the Club.

(Motion voted upon and carried.)

The Chair appointed Messrs. Whitelaw and Swasey as tellers to canvas the votes for officers. While the Secretary was temporarily absent with the tellers, Mr. James Ritchie was appointed Sec-protem. The Secretary, Corresponding Secretary, Treasurer and Librarian presented their annual reports. The Programme Committee presented three interesting reports: Prof. C. L. Saunders, one on Civil Engineering and Surveying; Mr. Walter Miller, one on recent progress in Mechanical Engineering; and Prof. C. S. Howe, one on some recent discoveries in Astronomy.

The tellers reported that the revised constitution had been adopted, having received 68 affirmative and only three negative votes. They also reported the following officers elected:

President, Jos. Leon Gobeille.

Vice President, Marius E. Rawson.

Secretary, Albert H. Porter.

Corresponding Secretary, Frank C. Osborn,

Treasurer, Noadiah P. Bowler.

Librarian, Clarence M. Barber.

Members of the Board of Managers of Engineering Societies, President Cady Staley, Samuel J. Baker.

The President announced that the new constitution having been adopted, the offices of Corresponding Secretary and Members of Board of Managers of Engineering Societies were abolished. He also stated that President Staley positively declined to serve another year, also that two directors should be elected. Motion

made and seconded that Mr. Frank C. Osborn be elected first Director. Motion carried unanimously. Mr. Samuel J. Baker was nominated for Second Director. Motion carried unanimously.

President elect Gobeille then announced the following:

Programme committee for the ensuing year: Benjamin F. Morse, Ambrose Swasey, Marvin W. Kingsley, Charles S. Howe, Sidney H. Short, Augustus Mordecai, Forrest A. Coburn.

Upon being called upon for a speech, the President, Mr. Gobeille responded briefly as follows:

"I do not think you expect me to say in words what is in my heart to-night, because I could not do it. I fully appreciate the honor of being elected President of a Club that has been presided over by so many eminent men. We see those men now from a distance. They are away from us, some in New York, some in other places, and I think I may say that no Society in the United States has had more distinguished men for Presidents than the Civil Engineers Club of Cleveland. However, unworthy I may feel myself, I will say, that I have been a member of this Club for eight years, and what I have observed during that time and thought of for the benefit of this Club I will use my best exertions to carry out this year. I will say further than this that you must bear with me in those shortcomings which are natural to young men—the youngest man you have ever had as President and the only man you have ever had as President who was not of national reputation, as far as I know. I want to say one more thing, and that is that under no circumstances whatever, will I be a candidate for re-election to this office. I want to say this now, because I am placed in a very embarrassing position, taking the chair as I do from Mr. Searles, and coming into the Presidency without giving it a single thought. I had no idea that I would be the choice of the Committee. I even had my choice for President, and for fear that possibly lightning might strike twice in the same place (which is against the old adage) I make this statement now.

I thank you very much indeed, and will say that I will do my very best to be worthy of the high honor you have conferred upon me."

The Vice President and Treasurer, also made brief addresses.

Messrs. Porter and Barber for the Committee on Banquet, reported that nearly all arrangements were completed, and that the prospect bid fair for a very pleasant entertainment.

A vote of thanks was extended to the retiring officers.

On motion, adjourned. A. H. PORTER, Secretary.

REPORT OF THE LIBRARIAN.

Few of the members of the Civil Engineers' Club of Cleveland are aware of the fact that we have a library.

Any member wishing to find a quiet secluded place where he may read or study without fear of interruption by any other member, will find such in the library of this Civil Engineers' Club.

So little is the club room used by the members as a reading room, that it seems as if the facilities for information or research are not appreciated by the Club. The advantage of membership in a library as large as the Case library is of itself of very great value to any student, and are we not all students? The Case library has books on almost every subject, but the Civil Engineers' club room has been prepared especially for engineers. On its tables are to be found every engineering paper that is published that any number of the Club has ever expressed a desire to read. We have some eighteen weekly journals and eight monthly (and the number is being increased) that are stacked upon our tables in the most inviting manner with a view of supplying the very latest and best information on every branch of engineering.

If you are a railroad engineer, a mechanical engineer, an electrical engineer, a sanitary engineer or architect, or if you are studying on any particular subject or class of subjects, there is new reading matter coming into our club room every week to fully repay you for spending from one to three hours each week.

Of course most of us have coming into our own homes almost as much weekly reading as we have time for, but there can be no doubt but that the club room supplies what few of us can afford to have on our own desks.

Beside the great Case library of which we are all members, there are in our club room 142 bound volumes that are the exclusive property of the Club. There are some .00 unbound volumes of pamphlets that pertain strictly to engineering subjects. These include the proceedings of the American Society and of the Civil Engineers' Club of Philadelphia, as well as papers and reports from nearly all the clubs of this country.

Now let me say that it is the purpose of the librarian and of the Case library to supply the club room with all the reading matter that is desired, and if any member wishes to see on our tables any journal that is not there, if he will kindly make known his wish to the librarian, the desired publication will be obtained if possible, and what is most important of all, is that all this is done at almost no expense to the Club. Our club room however, is sadly deficient in one item, viz: space. We have not room for books, our pictures or our members. If one-half of our members should on some particular evening decide to be at a meeting, we could not seat them in this room; even our ordinary meetings are frequently uncomfortable for want of room.

If our club is to grow either in interest or in numbers, we must have more room.

CLARENCE M. BARBER, Librarian.

SECRETARY'S REPORT.

To the President and Members of the Civil Engineers' Club of Cleveland:

GENTLEMEN: The records of the Club show the following as the result of the last year's work: There have been held during the past year sixteen meetings as follows: Annual Banquet on March 27th at which one hundred and sixty four members and visitors were present, twelve regular meetings at which the total attendance was two hundred and fifty nine members and forty one visitors, one picnic which eighty members and friends attended, one visiting day which twenty six members took part in, and one adjourned meeting held for the purpose of discussing and amending the proposed revision of the constitution

President Searles presided at nine of the meetings, Vice President Gobeille at five, Mr. W. R. Warner at one and Mr. C. M. Barber at one.

Thirteen papers, exclusive of those to be read at this meeting, have been read before the Club, and there has been one discussion on a technical subject.

The papers were as follows:

The Eiffel Tower from Foundation to Lantern, Mr. Ambrose Swasey.

Experience in the Construction of Gas Holder Tanks, Mr. G. A. Hyde.

Ferroid, a New Artificial Stone, Dr. Herman Poole.

The Almucanter, a New Instrument for Field Astronomy, Prof. C. S. Howe.

Methods of Wall Decorations, Mr. C. O. Arey.

Some Recent Constructions in Railroad Bridges, Mr. James Ritchie.

Lake Currents and the Proposed Opening of the Breakwater, Mr. W. P. Rice.

Railroads, Past and Prospective, Mr. J. H. Sargent.

The Muir Glacier, H. F. Reid, Ph. D.

Discussion on the Injurious effect of Cement on Lime Mortar, opened by Mr. C. O. Arey.

Transmission of Power by Belt and Rope, Prof. C. L. Saunders.

Annual Reports, Mr. C. P. Leland.

Methods of Determining the Cost of Manufacture, Prof. C. H. Benjamin.

Notes and Surveys on the Cleveland Water Works Tunnels, Mr. M. W. Kingsley.

At the commencement of the year the membership consisted of four Honorary, five Corresponding, five Associate, and one hundred and twenty one Active members, a total of one hundred and thirty five. Death has taken away two of that number, Mr. J. S. Oviatt and Mr. J. M. Blackburn. Two have resigned, Mr. N. S. Possons and Mr. J. C. Halstead. There have been admitted three Associate and twenty Active members, so that at present the membership consists of four Honor-

ary, five Corresponding, eight Associate and one hundred and thirty seven Active members, a total of one hundred and fifty four, or a net increase of nineteen during the year.

Owing to professional engagements which took him from the city President Searles has been unable to be with us at any meeting since September last. His absence has been keenly felt by all, for his watchful eye was over every detail of the Club work, and no one could have its interests more at heart than he. It is hoped that some time in the future it may be to his interest to locate in this city and be with us again.

At the meeting held in May Mr. C. O. Palmer resigned the office of secretary on account of business engagements which required all of his time, and prevented him from devoting any attention to the duties of the office, much to the regret of all, as he had been a most faithful and efficient servant of the Club, and had performed the duties in an eminently satisfactory manner.

The vacancy caused by the resignation of Mr. Palmer was filled at the June meeting by a special election.

Respectfully submitted,

A. H. Porter, Secretary.

Corresponding Secretary's report.

To the Civil Engineer's Club of Cleveland:

Gentlemen: I have the honor to present herewith my annual report as Corresponding Secretary. It is, in brief, as follows: During the past year I have to the best of my ability attended to the matters of routine, and answered the letters referred to me, and have also acted as Secretary and prepared the minutes at three meetings of the Club.

Very Respectfully,

S. J. Baker, Cor. Sec'y.

Treasurer's Report.

To the President and Members of the Civil Engineer's Club of Cleveland:

Your Treasurer begs to make the following report for the year, from March 1st, 1890 to March 1st, 1891:

Receipts.

1890 April 7.—To cash received from the retiring treasurer, S. J. Baker	$141 59
Fees and annual dues from twenty three new members	188.50
Annual dues from one hundred and eighteen Active, three Corresponding and five Associate members	735.00
	1065.09

Members not paid, two Corresponding, three Associate and nine Active, fourteen in all.

Disbursements.

By amount paid for rent of rooms in Case Library	$ 75.00
" " " " Journals, one hundred and fifty nine members	408.06
" " " " Case Library	118.00
" " " " Printing	126.41
" " " " Stenographers	46.53
" " " " Secretary's Desk	22.00
" " " " Emblems for J. S. Oviatt	15 00
" " " " Janitor for two years	20.00
" " " " Sundry items as per Vouchers	81 66
Cash in hand for Treasurer	152.43
	1065.09

March 10th, 1891.

Very Respectfully,

N. P. Bowler, Treasurer.

ENGINEERS' CLUB OF ST. LOUIS.

345TH MEETING, APRIL 1, 1891:—The club met at 8:15 P. M., in the club rooms, President Burnet in the chair and twenty-eight members and two visitors present. The minutes of the 344th meeting were read and approved. The executive committee reported the doings of its 107th meeting.

Mr. H A. Wahlert was proposed for membership.

Mr. John H. Curtis then read the paper of the evening on "Notes on Railway Locations." Mr. Curtis described some of his experiences in locating railways in various parts of this country and South America, and gave his conclusions in regard to the simplest and best methods to be pursued in such work. Discussion followed by Messrs. Johnson, Wheeler, Curtis, Moore, Burnet Crosby, Seddon, Van Sant, Bouton and Mersereau. Prof. Johnson differed with some of the conclusions drawn by Mr. Curtis, and thought more contour work should be done.

Mr. Van Sant described some of his experience and said he fully believed in contour work, but thought that it could only be used advantageously for certain portions of the work. The paper for the next meeting, April 15th, on "Practical Hints on Cement Testing," by P. M. Bruner, was then announced.

Adjourned. ARTHUR THACHER, Secretary.

346TH MEETING, APRIL 15, 1891:—The club met at 8:15 P. M., in the club rooms, Vice-President Eayrs in the chair and thirty-six members and two visitors present. The minutes of the 345th meeting were read and approved. The executive committee reported the doings of its 108th, 109th and 110th meetings.

Mr. Robert Moore, on behalf of the officers of the St. Louis Merchants' Bridge and Terminal Railway Company, extended an invitation to the members of the club to make a tour of inspection over the Elevated Railway and Merchants' bridge on Saturday, April 25th.

On motion the invitation was accepted, and the thanks of the club extended to the officers of the St. Louis Merchants' Bridge and Terminal Railway Company. The secretary was requested to notify members of the invitation.

Mr. H A. Wahlert was elected a member of the club. Messrs. G. T. Thompson and B. E Chollar were proposed for membership.

Mr. P. M. Bruner then read the paper of the evening on "Practical Hints on Cement Testing." Mr. Bruner first spoke of the uniformity of the results obtained in the European Testing Works, and presented a table of results obtained at the Berlin Works. The table gave the weight per liter, water required, temperatures, size, etc., the fineness of the particles being a most important consideration, as the coarser particles do not have any cementing effect; but when the cement is used neat they act the part of sand. It therefore follows that the clinker of the same kiln ground at different factories will yield different qualities of cement. The first test of cement in standard testing should be for the percentage that will pass a sieve of about 35,000 meshes to the square inch.

Discussion followed by Messrs. Ockerson, Seddon, Bruner, Moore, Johnson, Crosby, Eayrs, Taussig, Wheeler, Russell and Long.

Mr. Seddon called attention to the fact that great variation was caused by briquettes not being properly held by the clip—in his own experience amounting sometimes to 20 per cent.

Prof. Johnson illustrated a method of holding the briquette in the clip by means of movable steel strips.

Mr. Bruner thought a better method could be devised by imbedding a screw in the briquette.

Mr. Russell described a number of tests made with three methods, and stated that the German method gave results with the widest variations.

Adjourned. ARTHUR THACHER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

280TH MEETING, APRIL 18, 1891:—The 280th meeting of the Society was held at its rooms, Wednesday evening, April 8, 1891, at 8 p. m. President L E. Cooley in the chair and over 50 members and visitors present.

Owing to the amount of business before the Society the minutes of the last meeting were passed without reading, and the Secretary announced the following elections of members by the Board of Directors:

Edward O. Reeder, Chas. E Laas, Arthur G. Baker, Wm. F. Hogan, Nelson O. Whitney, James C. Hallstead, Howard N. Roberts, A. U. Leonhaeuser, Thos. Appleton.

The following applications were also received:

J. C. Slocum, W. C D. Gillespie, Wm. H. Hendren, Theodore W. Parvin, Morgan Walcott.

Letters were then read from Mr. Chas. Hansel, of Springfield, Ill., Consulting Engineer, Railroad and Warehouse Commission, and Mr. R R. Bourland, of Peoria, Ill., members of the Society, in regard to the appointment of Consulting Engineer for the Railroad and Warehouse Commission, the matter having been brought up in the Legislature now sitting. The following preamble and resolution accompanied Mr. Bourland's letter, and it had already received the attention of the Board of Directors, who cordially endorsed the proposition:

WHEREAS, The 20th Annual Report of the Railroad and Warehouse Commissioners of the State, submitted to the Governor, January 1, 1891, in conclusion under the title "Appropriation," page 67 says:

"That in our judgment an additional appropriation, placed at our disposal, for the purpose of enabling us to employ * * * a competent and experienced civil engineer to be designated as the Consulting Engineer of the Commission, would be an expenditure wisely made," and

WHEREAS, A sum has been fixed in an appropriation bill which has been presented to the General Assembly, now convened at Springfield, as compensation for an incumbent of such office, therefore be it

Resolved, That we do heartily endorse the recommendations of the said board, believing it is necessary to the carrying out of its functions as a Railroad board, that the office be equipped with sufficient force to enable it to make careful, frequent and intelligent examinations of the physical condition of the railroads of the State, and further be it

Resolved, That it is the sense of the Western Society of Engineers that such action on the part of the General Assembly as will result in provision for the appointment of and compensation of such officer, would be for the good of the State, and should be taken, and we do hereby strongly recommend the passage of the clause in the appropriation bill now under consideration, looking to that end. And it is further

Resolved, That a copy of this preamble and resolutions be furnished each member of the present General Assembly.

The President called for a second to the resolution, and Mr. Benezette Williams responding, the resolution was formally voted upon and passed

The President then called the attention of the Society to a matter presented by the Committee on "Topographical Survey of Illinois," relating to the expediency of an effort to present the subject before the present Legislature. The Illinois Society of Engineers and Surveyors as well as the State Geologist are also interesting themselves in the work.

The Chairman of the Committee, Mr. H. B. Alexander, on being called presented the following:

The reorganized Committee on Topographical Survey of Illinois has had two meetings since appointment, March 4th. A plan of action has been formulated and investigations inaugurated. Each member has a definite duty assigned, so that we may hope for practical results in the near future in bringing to the notice of the profession and to the people at large the benefits arising from such a survey, with methods and cost of doing the work and description of results that will be obtained. A Bill has been drafted for the consideration of the present General Assembly now in session, and, though we may not be able to obtain desired legislation at this session, we will be able to bring the question before the people at once in this manner in a practical way.

I would recommend that some action be taken on this bill to-night, if practicable, by the Society, so that it may be sent to Springfield with some show of professional consideration.

In this connection I might freely state that all the civilized nations of the world are engaged in accurate Topographical surveys, and that the United States is the most backward of any country in this character of work. England has about finished one of the most elaborate surveys yet undertaken, a survey that has been in progress now for over a century, and costing over $200 per square mile.

Regarding surveys of individual States, New Jersey can claim the distinction of being the first one to finish such a survey and publish the results in an elegant atlas, the scale adopted being one inch to the mile, with contours, at intervals, in the more level parts, of 10 feet, and 20 feet for the mountainous or hill regions.

The following statistics of the New Jersey Topographical Survey, taken from the Annual Report of the State Geologist for 1887, is interesting:

Area, 7,475 square miles.

Number of miles of leveling, 14,575, or 1.97 miles per square mile of area.

With $10^{2}/_{10}$ stations to the square mile.

No of miles of odometre traverse, 18,768, or 2.52 miles and 2.53 stations per square mile.

Also, 1,114 miles of Primary levels and 956 miles of Transit Traverse.

The following is the time record of the survey distributed to each portion of the work

Leveling and sketching simultaneously	8,082	days work.
Sketching, without leveling	760	"
Primary leveling, without sketching	708	"
Traversing with odometre	2'145	"
Transit traversing	713	"
Triangulation	467	"
Office work, including platting, etc	4,159	"
Supervision	892	"
Total	17,916	

No deduction is made for Sunday or Stormy weather in the above record, and it presents the time in days work of one man.

The total cost of field work and preparation of manuscript maps on a scale of 3 inches to a mile has been $54,744.58, which amounts to $6 93 per square mile, or $1^{1}/_{12}$ cents per acre.

Massachusetts has also been engaged on a similar survey, the field work having been completed, but results as yet unpublished, I believe. Connecticut has recently undertaken a survey and $25,000 appropriated to carry on the work for the year. I understand that Ohio is also engaged on a survey, also Minnesota. New York has been working in this line for several years, and has a State Engineer as one of the permanent officers of the State. Georgia, North Carolina, Alabama and Michigan have done more or less in this direction, all in connection with the Geological surveys of the State.

Illinois has done nothing so far, and yet it has more interests that would be directly benefitted by such a survey than any other, perhaps, in the United States.

The agricultural, mining, manufacturing, transportation, scientific and educational interests all call for definite information regarding the surface features of the State, and when it becomes known how cheaply the work can be done, it would seem an easy matter to obtain the necessary appropriations to carry on the work. I have looked over the cost of doing the work and believe it could be done in Illinois for about $20 per square mile. This amounts to only 3 cents an acre, or on basis of assessed value of $20 per acre this would amount to $^{15}/_{100}$ of one per cent on assessed valuation.

Again there are 56,000 square miles in the State, which at $20 per square mile would give a total cost of a little more than $1,000,000, and if we allow 20 years to complete this survey, this would amount to $50,000 per year, or as there is a population of about 4,000,000 in the State, the survey would cost about 25 cents per head of population, or only $1^{1}/_{4}$ cents per head per annum.

I desire to impress upon every member the importance of this work, with earnest request that each one devote same little time among friends, political, business and scientific, in urging early action and their hearty support, and influence in the way of procuring necessary legislation.

Thanks are due Prof. T. C. Mendenhall, Supt. U. S. C. & G. survey, for valuable information furnished by letter and for printed documents; also to I. S. Upson, Asst. in charge of office Geological survey of New Jersey for reports of that survey.

Mr. Alexander then presented the following resolution, which was seconded by Mr. E. L. Corthell and carried:

Resolved, That the Board of Directors be authorized to consult with the Committee on Topographical survey for Illinois, with a view to such action as may be immediately expedient for the presentation of the subject before the present session of the General Assembly of Illinois. and that the progress report of the Committtee be incorporated in the proceedings.

The President explained that the Committee had prepared a rough draft of a bill on the subject, and that in co-operation with other parties interested in the State, the design was to present the bill more as an educational matter to get it before the people, and without, in any way, committing the Society.

Mr. Isham Randolph then read the following eulogy on the late Mr. Samuel H. Miller:

Samuel H. Miller.

Mr. President and comrades of the profession: In every long contested battle there comes a time when the roar of the guns ceases and the white flag proclaims a truce. A truce not as a prelude to capitulation but that living heroes may bury their dead comrades who with their life's blood have poured out a libation to liberty, to glory and to honor. And so in the battle of life ever and anon there comes a pause in which with hearts and heads bowed down we must pay the last tribute to all that is mortal of one or another of those who have stood in the ranks with us until the summons which must come to each in turn, bade him "fold the drapery of his couch about him and lie down to great dreams."

Just here I ask a truce from the business of this evening that we may fittingly recognize the death of one of the veterans of our profession I am not sure that he was a member of this Society, but I know that among those who are there are many like myself who valued the friendship and esteemed the work of Mr. Samuel H. Miller, and who feel that his standing in the profession was such as to make it right and proper that this representative body should do honor to his memory. Mr. Miller died at the Presbyterian Hospital in this city on the morning of Wednesday, March 18, 1891.

He was born of Quaker parents in Kensington, Ohio, in 1829. His educational advantages were not very liberal but they seem to have been sufficient to serve as a basis for his after acquirement of knowledge by study and observation, which his natural ability enabled him to use with such effectiveness as to place him in the front rank of his profession. His first engineering work was on the River Division of the Cleveland & Pittsburgh R. R., where he served as rodman. The date and duration of this service I have been unable to obtain, in fact in most of the dates I shall use I shall be compelled to use the indefinite term about. In 1862 or thereabout he was in charge of the reconstruction of the Mahoning branch of the Atlantic & Great Western with headquarters at Meadville, Pa. After that he did a great deal of work for proprietary companies in the Oil Creek region. In 1872 he occupied the position of chief engineer of the Hannibal & St. Joe R. R.

About the year 1874 he went to Cleveland as assistant city engineer with entire charge of the Cleveland viaduct; that work occupied him about five years. In 1879 he took charge of the Chicago & Grand Trunk R. R., then building from Valparaiso to Chicago, as engineer for the contractors. From that work he passed to the chief engineership of the Chicago & Eastern Illinois R. R., which position he held until March, 1890. At the time he was stricken with the fatal illness which ended his useful career he was in charge of the construction of the second track of the Chicago & Western Indiana R. R., between Oakdale and Dalton, including the erection of a

double-track draw-bridge across the Calumet river at Riverdale. In his private life Mr Miller was modest and unassuming—rather shunning society on account of his infirmity of deafness—but with his friends he was genial and companionable. His studious habits and cultivated mind made his conversation both instructive and entertaining. He had mastered the French language and was well read in the best literature of the profession in that tongue and kept abreast with the best theory and practice of his day. He was honorable in all things and faithful to friendship and to duty. A man of strong character, with clear perceptions of right and a steadfastness in maintaining it which never faltered.

His illness was a short and painful one, and there was much in it to appeal to the heart's sympathies. He had every care and attention which abundant means could command, but he was a bachelor, and the simple statement of that fact carries with it an idea of desolation. His last hours were without the sweet consolation which a wife's endearments or a daughter's ministering care bring to the couch of suffering. There was not "lack of woman's nursing," but there was "dearth of woman's tears" when he sank into the sleep which knows no waking.

The ranks will close up, and the gap which he has left will be filled, but he will not be forgotten while the substantial monuments which he left here and there throughout our land, remain to attest his ability and skill.

Mr. John F. Wallace moved that the remarks of Mr. Randolph be printed in full in the proceedings of the Society, and that a copy thereof be forwarded by the Secretary to the Secretary of the American Society of Civil Engineers. Carried.

The President then called up the subject of the evening, Mr. Corthell's paper on "An Enlarged Waterway from the Great Lakes to the Atlantic Seaboard."

In relation to this the Secretary read congratulatory letters from Messrs. I. C. Chesbrough, William T. Blunt and R. B. Mason.

The abstract of the paper and the written discussions to hand will be printed in the April issue of the *Journal*.

In presenting the subject Mr. Corthell said:

MR. CORTHELL:—This is too important a subject, and too broad in its scope to expect of any one to cover the entire ground even in its general features, in the time that would be allotted to the author of a paper like this. I wish to say as prefatory to my remarks, that it is now nearly a year since I took up this subject professionally, to study it in all its bearings and to ascertain from the facts which I have been trying to obtain from various sources, whether it is possible to build an enlarged waterway for the commerce of the Great Lakes, a waterway that will carry them to the seaboard. Perhaps what I have written on my portfolio which I have carried all over the United States and Mexico, may give you my own idea, it is—Chicago, Duluth, Liverpool: that is the problem. Mr. Cooley and myself during the last three or four years, have had more or less talk on this subject; we have discussed it together, we have hoped together that there might be at some time an enlarged waterway for commerce between the Atlantic seaboard and the Gulf of Mexico. The subject southward he has had, as you all know, much to do with, and I think not only this community, but the community embraced in the entire Mississippi valley should thank him for his work.

I took up this subject, or my part of it, realizing that I had a very large undertaking before me. Last summer, in order that I might get reliable data by seeing for myself and by talking myself with those that knew about the subject more than myself, I partly for recreation and partly in mind of this business, went through Canada and as far as the Chignecto Isthmus. I had previous to that had correspondence with prominent Canadian engineers, particularly Mr. Thomas Keefer of Ottawa, with Mr. Kennedy of Montreal, with Mr. H. F. Perley, Chief Engineer Public Works Department, and of course Mr. H. G. C. Ketchum, of the Chignecto Railway. I spent several weeks on this examination and came back to Chicago to work up the data, when I found that I was still lacking some of the most essential data required for a careful thorough discussion of this subject, and sent one of my associates, Mr Robinson, member of this Society, with letters and instructions to Ottawa, Montreal and Toronto, to get what was lacking, in order that the information might be complete. It is needless to say that I have an office full of it, more

than I could digest in years of time. Wishing to have access to the most reliable information, that on file in the department of public works, Canada, I armed Mr. Robinson with various letters which I procured, some of them through the kindness of some of my friends and officials; Mr. Kramer of our country, gave me a letter to the minister of public works; through Mr. Cooley, our president, I obtained a very valuable and useful letter from Gov. Fifer also to the Minister of Public Works, and I cannot forbear in this introduction, to mention a letter which Mr. Cooley at that time wrote to a prominent commercial man of this city asking for this letter. It gives my own views as to the object I had in view, and it clearly and pointedly stated the object and covered the ground. To show how kindly the letter that was given in reply to this and other letters were received, I have simply to state that the archives of the Canadian government at Ottawa were opened to inspection for making copies of everything that they had on record and many things that were not in print and Sir Hector Langevin went so far as to have a manuscript copy made of the report of Mr. Walter Shanley, a pamphlet of about 55 pages, and the greatest interest was evinced by the officers of the Canadian Government who were asked to contribute information. Mr. Keefer and Mr. Kennedy, of Montreal, and other engineers all through Canada who were requested to assist us, did so with great readiness, as a result, and partly as a matter of courtesy, I thought it was the proper thing to do to write this paper for the Canadian Society of Engineers of which I was a member and to which I owe a great deal of information. The paper, which is quite extensive, has been read before that Society recently, and it is by the request of the officers of this Society that I have written and will now read such facts as I think may be necessary to-night for an abstract of that paper, with some slight omissions, regretting very much that there is so much detail in the work, when we come to a detailed examination of the various routes that have been proposed in the way of plans and estimates, and also particularly in the way of commercial data, that I cannot possibly give it to you until it is put into your hands, which I hope it will sometime be, through the Canadian Society of Engineers as a printed pamphlet. I have requested that a large number be sent to me whenever the paper is printed, so that I can distribute it among those of this Society who would like to have it.

The Secretary read the discussion presented by Mr. Onward Bates, and was followed by Mr. St. John V. Day, who remarked that his written discussion was confined to the printed abstract of Mr. Corthell's paper.

After some questions on the Ship-Railway, Mr. Benezette Williams presented a discussion, introducing it by also saying that his discussion might have differed somewhat had he have heard Mr. Corthell's additional remarks.

The hour of adjournment having been reached, the interest was such that a motion was made to continue, there being more discussion, but it was compromised and the Secretary closed by reading a discussion by Prof. Marx.

The question of continuing the discussion at a special or the next regular meeting was debated, and resulted in postponement until next regular meeting, when it was thought there would be sufficient time to spare after the "special order" for that date—the discussion of Mr. Richard P. Morgan's resolution on change of the name of the Society.

Adjourned. JOHN W. WESTON, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. X. June, 1891. No. 6.

This Association, as a body, is not responsible for the subject matter of any Society or for statements or opinions of any of its members.

SOME EXPERIMENTS TO DETERMINE THE STRENGTH OF AMERICAN VITRIFIED SEWER PIPE.

BY MALVERD A. HOWE, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read February 4, 1891.]

In searching for data concerning the strength of American vitrified sewer pipe, no record of systematic tests of pipe manufactured by different parties was found. In order that such a record might be available, the following described experiments were made.

That a fair average strength might be obtained from the experiments, pipe was secured from manufacturers as far east as Wilmington, Delaware, and as far west as St. Louis, Mo., pipe being obtained from the following manufacturers.

1. Akron Sewer Pipe Co.
2. Anderson Bros., Anderson, W. Va.
3. Anness & Lyle, Manufacturing Co., Woodbridge, N. J.
4. Blackmer & Post, St. Louis, Mo.
4. Buckeye Sewer Pipe Co.
6. Delaware Terra-Cotta Co., Wilmington, Del.
7. Diamond Fire Clay Co., Uhrichsville, Ohio.
8. Evans & Howard, St. Louis, Mo.
9. Excelsior Sewer Pipe Works, Calumet, Ohio.
10. Hill Sewer Pipe Co.
11. Hill, Sperry & Co.
12. McMahon & Porter, New Cumberland, W. Va.
13. Pittsburgh Sewer Pipe and Fire Clay Co., New Brighton, Penna.
14. Robinson Bros., & Co.
15. Geo. S. Sperry.

When the pipe was not purchased in the open market it was furnished

with the understanding that if the results of the experiments were published the names of the manufacturers would not be specified, hence in the following descriptions etc., each manufacturer's pipe has been designated by a letter of the alphabet.

As fast as the pipe was received at the laboratory, each length was carefully measured, weighed and marked, and thereafter was only known by its mark or number. The mean diameter and thickness of each length of pipe tested is given in Tables I, II, III and IV; the other measurements have been omitted as they have but little or no influence upon the results of the experiments.

The pipe was subjected to the following tests:

I. *The Hydrostatic Test*, to determine the bursting strength of the pipe and also the tensile strength of the material.

II. *The Drop Test*, to determine the relative capacity of the pipe to resist "percussive action."

III. *The Concentrated Load Test*, to determine the strength of the pipe when subjected to a concentrated load.

IV. *The Uniform Load Test*, to determine the strength of the pipe when subjected to external pressure under the conditions found in practice.

V. *The Cement Joint Test*, to determine the strength of joints made of cement when subjected to hydrostatic pressure.

APPARATUS AND METHODS.

Hydrostatic Test. In making the hydrostatic experiments to determine the ultimate tensile strength of the material composing the pipe, three methods were employed.

Method No. 1. The principal features of the apparatus used in this method are shown in Fig. 1. The ends of the pipe were closed by rubber gaskets and wooden heads which were drawn together with bolts until a water tight joint was obtained between the heads and the ends of the pipe. The pipe was then filled with water, the pump (see Plate II) connected to the pipe passing through the upper head and water forced in until the pipe was broken.

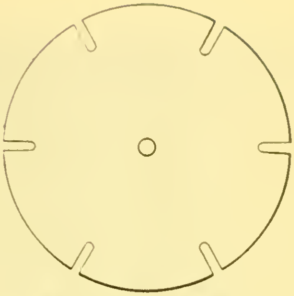
Method No. 2. This apparatus differed in only one particular from that used in Method No. 1, viz; no end pressure was brought upon the bell of the pipe, the rubber gasket being placed as shown in Fig. 2.

The method of filling and bursting the pipe was the same as in Method No. 1.

Method No. 3. In this method *no end pressure* was brought upon the pipe, the ends of the pipe being closed with leather cups clamped between two pieces of wood which were prevented from slipping out of the pipe when under hydrostatic pressure by heads and bolts similar to those used in the previously mentioned methods, as shown in Fig. 3. A cross section of the wooden pieces clamping the leather cups and also the die for forming the cups are shown in Figs. 4 and 5.

Sole leather was employed in making the cups which were formed in the die shown in Fig. 5, by forcing the leather, after being soaked in water,

APPARATUS USED IN SEWER
— PIPE EXPERIMENTS. —
— 1890. —



PLAN OF HEADS.

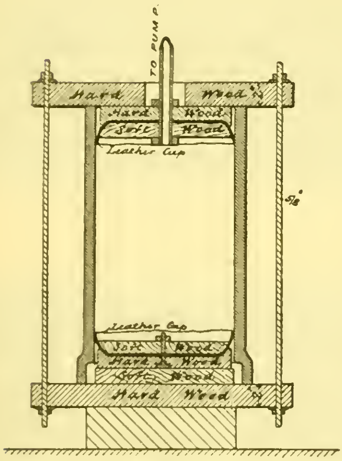


FIG. 3.

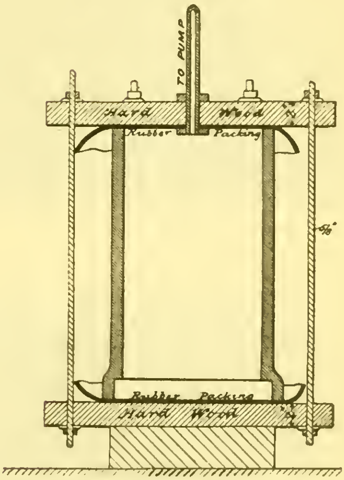


FIG. 1.

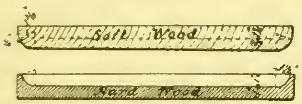


FIG. 4. SECTION OF WOODEN CLAMPS FOR LEATHER CUPS.

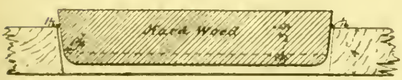


FIG 5 SECTION OF WOODEN DIE USED IN FORMING LEATHER CUPS.

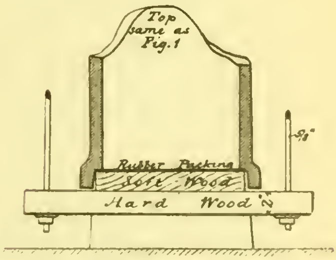


FIG. 2.

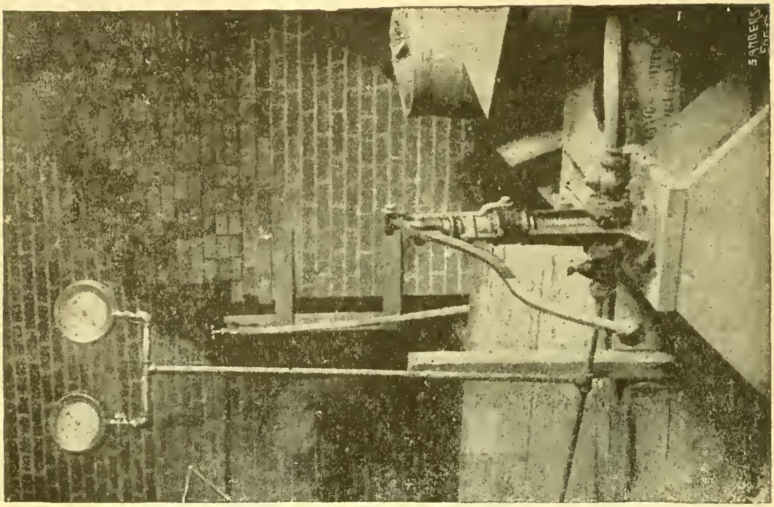


PLATE II.

PLATE I.

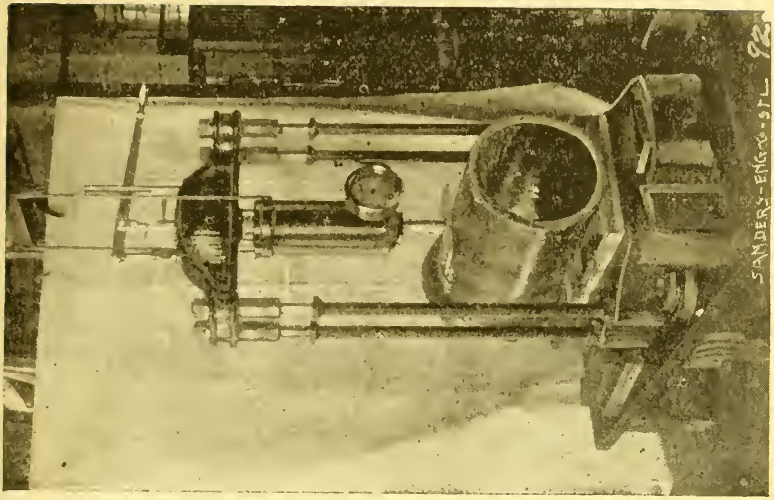


PLATE IV.

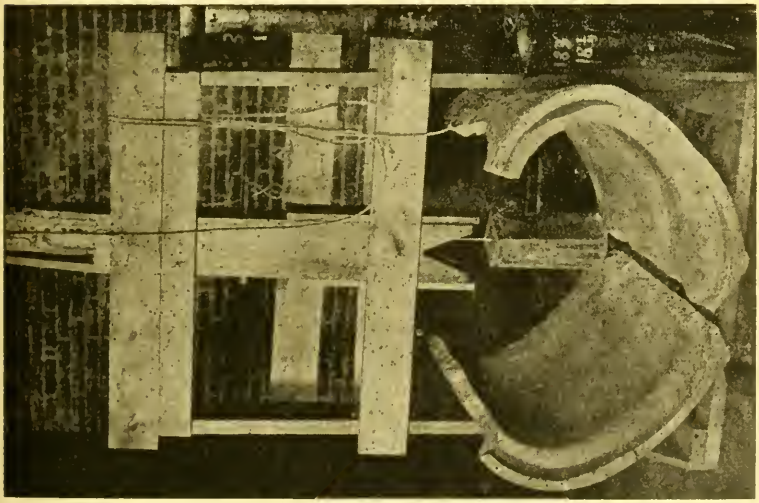


PLATE III.

ahead of the hard wood plug with the hydraulic press shown in Plate IV, each cup being subjected to a pressure of about fifteen tons. Before removing the leather from the form the edges were shaved down to a thin edge and then it was removed, placed in the clamps and kept wet ready for use. The cups for pipe having a diameter greater than twelve inches were formed in a similar manner but the pressure was applied with another apparatus.

In filling the pipe a connection was made with the city water mains and the pipe subjected to their (the water mains) maximum pressure and then the connection was closed and the pump brought into action.

The pump and gauges shown in Plate II were used in all the hydrostatic tests. The gauge on the left was used for all pressures below two hundred pounds and that on the right for greater pressures.

Plate I, shows the apparatus of Method No. 3, which was employed in testing pipe above twelve inches in diameter.

Drop Test. Plate III shows the essential features of the apparatus used in these experiments. The pipe to be tested was supported on two pieces of pine, each two inches wide, placed sixteen inches center to center and so arranged that the falling weight would strike the pipe near its center and midway between the supports (the pipe shown in Plate III is at right angles to the usual position of the pipe, it being too long to go between the supports of the apparatus); the falling weight consisted of a wooden box filled with cast iron cubes and weighing eighteen pounds.

The end of the box striking the pipe was made of a rounded piece of hard wood. The weight was drawn up by means of a rope passing over a pulley (not shown in Plate III) at the top of the guides. The distance passed through by the weight was regulated by a pin passing through the guide box. In making a test the weight was allowed to fall upon the pipe from a height of twelve inches and if the pipe was not broken at the end of five falls the pin was moved so that the height of the fall was eighteen inches; if the pipe was still unbroken at the end of five falls from this height the height was increased to twenty four inches and so on until a height of thirty inches was reached which was the maximum height of fall used.

Concentrated Load Test. Plate IV shows the method of making these tests. The pipe was supported on two pieces of pine, each two inches wide and placed sixteen inches center to center, the load was slowly applied midway between these supports.

Uniform Load Tests. The pipe was placed in a wooden box eighteen inches wide, eighteen inches deep and three feet long and completely surrounded with sand. Pressure was applied to the surface of the sand through a hard wood block twelve inches wide, eighteen inches long and four inches thick by the apparatus shown in Plate IV, the center of pressure being as near as possible midway between the spigot end of the pipe and the commencement of the bell. Pressure was applied until the pipe was heard to crack.

In nearly every case the pressure was afterwards increased until the limit of the apparatus was reached.

Cement Joint Tests. The apparatus and methods used were the same as described under Hydrostatic Tests.

RESULTS OF THE EXPERIMENTS.

Hydrostatic Tests.—The results of these tests are given in Table I for each piece of pipe tested, with the exception of those results which were rejected.

In Table VII is given the average tensile strength of each class for the different methods employed in testing the pipe and also the general average of all the results obtained for each class; the averages for the different classes varies from 265.6 pounds for class C to 1081.8 pounds per square inch for class N, while the general average of all the results is 600.4 pounds per square inch.

In table IX is given the average tensile strength of each size of pipe as tested by the different methods as well as the general average tensile strength for each size of pipe.

In table VIII is given a comparison of the thicknesses of pipe required to just stand a hydrostatic pressure of one hundred pounds per square inch, (under the assumption that the material has a tensile strength of six hundred pounds per square inch), with the thicknesses of the pipe as manufactured.

It is seen that in every case the thickness as manufactured is either equal to or greater than the thickness required to stand the hydrostatic pressure of one hundred pounds per square inch.

In computing the general average tensile strength, 600.4 pounds per square inch, no account was taken of the reliability of the different methods employed. If the results obtained for the classes from A to G inclusive be combined, the average is 495.7 pounds per square inch, which is considerably *less* than the general average 600.4. Combining the results obtained for classes H to P inclusive, the average is 692 pounds per sqnare inch, which is considerably *greater* than the general average, 600.4 pounds.

Since all of the results for classes H to P inclusive were obtained with the apparatus of method No. 3, this would seem to indicate that the use of methods I and II had a great tendency to decrease the magnitude of the results.

Combining all of the results obtained by method No. 3, the average is 673.6 pounds per square inch, which still indicates that methods Nos. 1 and 2 did not give as high results as method No. 3.

An explanation of this discrepancy of the results obtained by different methods will be given in discussing the reliability of the results of the entire series of experiments.

Drop Tests.--In Table II is given the results of the individual tests. The values of *Wv and *Wh have been computed for each test, with the view of having something as a basis for comparing the strength of different pipe. The values of Wv were used by †English experimenters

†See Latham's Sanitary Engineering.

*W = the weight of falling box = 18 lbs., v = velocity in feet per second of the falling weight, and h = the distance passed through in feet by the falling weight.

for comparisons, but it appears to the writer that *Wh* forms a better basis. In the majority of cases *Wh* does not represent the energy which the pipe was capable of absorbing, but it is probably as good a basis for comparison as can be obtained for drop tests.

Out of the seventy-nine lengths of pipe, twenty lengths failed at the first fall of the weight; of these twenty lengths, nine lengths had fractures differing in color from those of the same class for the hydrostatic tests giving the best results, and hence the failure of these lengths can be partially attributed to the burning of the pipe. Usually the lengths which failed at the first fall of the weight were at least eight inches in diameter.

Of the eleven lengths of pipe whose failure cannot be attributed to the burning, only three lengths were under ten inches in diameter. In only two classes does the test seem to have been too severe, namely, classes J and L.

Concentrated Load Tests.—Forty-two experiments were made and the results of each test are given in Table III; the average results in round numbers are as follows:

Average	of 5	results	for 4″	pipe	4,100	pounds.
"	" 1	"	" 5″	"	3,100	"
"	" 5	"	" 6″	"	2,700	"
"	" 7	"	" 8″	"	2,400	"
"	" 2	"	" 9″	"	3,180	"
"	" 7	"	" 10″	"	2,200	"
"	" 14	"	" 12″	"	2,700	"
"	" 1	"	" 15″	"	3,300	"

Owing to the very small number of any size of the same class being tested, the relation between the color of the fracture and the greatest strength could not be determined, but as the pipe almost invariably failed by splitting longitudinally, it is probable that pipe having the greatest tensile strength would support the greater loads in this test.

Uniform Load Tests.—Of this series twenty-six experiments were made, the results of which are given in Table IV.

The averages in round numbers are as follows:

Average	of 5	results	for 4″	pipe	17,300	pounds.
"	" 8	"	" 6″	"	12,000	"
"	" 5	"	" 8″	"	 5,900	"
"	" 6	"	" 10″	"	 4,600	"
"	" 2	"	" 12″	"	 5,000	"

With the very small amount of sand above the pipe, which could not be avoided with the apparatus at hand, the smallest average load is 4,600 pounds, or nearly one ton per foot length of the pipe.

The majority of the lengths of pipe failed by splitting longitudinally. Although in many cases a load of fifteen tons was applied, yet in no case did the pipe collapse: the pipe broke into many pieces, but these seemed to act as arches and it required considerable labor to separate them after the test.

Cement Joint Tests.—The results of these tests are given in Table V. Throughout these tests Louisville Black Diamond cement was used. The joints were carefully made and allowed to harden, no care being taken to keep them damp.

The results given in Table V indicate that Methods Nos. 1 and 2 gave larger results than Method No. 3. This is easily explained as follows: In Methods Nos. 1 and 2 the pipe was held rigidly in place, and hence, the only way the joint could fail was by having the cement forced out by the water. In case the lengths of pipe had smooth ends there was little or no chance for the water to get between the cement and the pipe, and hence the joint would hold until the pipe failed. In Method No. 3 there was nothing to prevent the pipes from separating, and hence, as soon as water worked in between the ends of the pipe they immediately commenced to separate when the friction between the cement and the pipe was overcome: this friction must be very small, judging from the results.

Ring joints are not as liable to fail as the ordinary bell and spigot joints when the pipe is prevented from separating, but has but little more strength when the pipe is not prevented from separating. The improved joint with grooves shows a greater strength, as it should, since its strength depends both upon the friction between the cement and the pipe and the shearing strength of the cement.

In all of the tests made, a careful record was made of the manner in which the pipe failed; the number of pieces and the color and appearance of the fracture.

As a rule the pipe failed first by splitting longitudinally, and second by cross-breaking. The pipe having the greatest strength usually had even fractures, and in many cases the pipe subjected to the hydrostatic pressure split into halves.

The number of pieces, of course, was quite variable, the uniform load tests showing the greater number.

As a rule the fractures indicated that the pipe was apparently composed of a great number of concentric cylindrical layers, and it was not unusual to find these layers separated in places.

In the hydrostatic tests the color of the fracture was, with hardly an exception, the criterion of strength, each class having its particular color corresponding to the greatest strength.

The pipe having the greatest strength had fractures *uniform in color throughout*, and any departure from this showed a decrease in strength. The weaker pipes of any class showed a fracture of two colors in three layers usually.

With the exception of the pipe of classes L, M and N which had a high tensile strength, the pipe having the greatest tensile strength (judging from the color of the fracture) stood the greater number of blows in the drop tests. Classes L, M and N were brittle and broke easily.

Reliability of the Methods Employed.

Hydrostatic Tests.—The results of these tests show that Methods Nos. 1 and 2 did not give as high results as those of Method No. 3.

This can be explained as follows: In Method No. 1 the ends of the pipe being uneven, a large end pressure was required in order to obtain water-tight joints; in case this end pressure was not uniform, there would be a tendency for the pipe to fail by splitting; again, since the pipe rested on the bell ends, this end pressure had to be transmitted to the main portion of the pipe through the curved shoulder, and any variation in the uniformity of this stress would have a tendency to crack the bell.

For cast-iron pipe this method has no practical faults since the strength of the iron pipe is so great; but for vitrified pipe it has the serious fault mentioned above. It was not an unfrequent occurrence to have the pipe split end to end before being subjected to any hydrostatic pressure when this method was used.

Method No. 2 has the same objections as No. 1, with the exception that the bell was not subjected to stress.

Method No. 3 had none of the above objections, and the results obtained represent the actual strength of the pipe. Owing to the variation in the diameters of the pipe, trouble was experienced in getting the leather cups into the pipe, and a few lengths were broken by forcing the cups. Usually the cups occupied about two or three inches at each end of the pipe, but occasionally it was impossible to have them occupy more than one inch.

The apparatus for the remaining tests appeared to be quite satisfactory, and the results reliable, with the exception of that used in the uniform load test where the amount of sand surrounding the pipe was too small.

Conclusions.

1. From the results obtained it seems safe to conclude that the average ultimate tensile strength of the material composing American vitrified sewer pipe, is, *at least*, 600 pounds per square inch.

2. That the average pipe will safely stand any ordinary shock or blow.

3. That the average pipe will support 2,000 pounds at its center when supported at points sixteen inches apart.

4. That the average pipe will support 2,000 pounds per lineal foot when bedded in sand.

5. That cement joints made with the ordinary bell and spigot are not safe when subjected to pressure, unless the pipe is prevented from moving longitudinally.

6. That ring joints are but little stronger than the ordinary bell and spigot joints when the pipe is unconfined.

7. That the improved joint with grooves is stronger than the two mentioned above.

8. That if the pipe is confined, any of the three joints mentioned, if carefully made, will probably hold as long as the pipe remains whole.

NOTE.—It was found that strong pipe could be selected by striking it lightly with a piece of steel; the strong pipe having a peculiar clear ring.

NOTE.—By mistake a lot of cement pipe was procured. When subjected to the hydrostatic test the maximum pressure obtained was about forty pounds per square inch when the water was forced through the sides of the pipe.

As an experiment a six inch pipe was closed at one end and filled with water; inside of one minute the water had soaked through the sides of the pipe and ran down the outside.

The use of this pipe for sewers needs no comment.

NOTE.—All of the experiments were made in the Laboratories of the Rose Polytechnic Institute.

The writer is much indebted to Professors Mees, Gray, Brown and Ames, for valuable assistance and suggestions.

Table I. Results of the Hydrostatic Tests.

Mark.	Class.	Mean diam. in inches.	Mean Thickness in inches.	Pressure in Lbs. per sq. in.	*Ult. Strength per sq. in. in lbs.	Method employed.
2	A	8.00	0.75	50.0	266	2
3	A	7.95	0.75	50.0	265	2
4	A	12.05	1.00	175.0	1054	3
5	A	11.95	1.01	94.5	559	3
8	A	6.20	0.79	148.0	581	2
9	A	12.00	0.98	152.0	931	2
10	A	10.05	0.84	141.0	870	2
12	A	12.15	1.02	139.0	828	3
15	B	12.00	1.08	81.0	450	3
18	B	12.10	1.08	115.0	644	3
24	B	9.95	0.95	148.0	775	3
25	B	8.30	0.82	28.0	142	1
27	B	8.15	0.85	50.0	240	2
29	B	8.05	0.82	50.0	245	2
31	B	6.15	0.83	124.0	459	2
32	B	6.20	0.85	78.0	284	1
34	B	6.15	0.81	131.0	492	2
38	B	5.05	0.64	40.0	158	1
40	B	4.10	0.67	195.0	596	3
43	B	4.05	0.71	140.0	399	1
46	C	12.15	1.12	72.0	391	2
48	C	12.25	1.10	46.8	261	3
50	C	8.00	0.89	105.0	472	1
51	C	7.85	0.89	105.0	463	3
53	C	7.95	0.90	124.0	547	3
61	C	4.00	0.70	130.0	371	1
63	C	4.00	0.70	160.0	457	2
64	C	4.00	0.69	200.0	580	1
65	D	12. 0	0.98	66.0	404	3
70	D	12.05	1.00	143.5	865	3
71	D	9.70	0.90	166.0	894	2
73	D	9.65	0.92	60.0	314	2
77	D	7.75	0.83	165.0	770	3
79	D	7.75	0.82	195.0	921	3
81	D	7.80	0.84	81.0	376	2
83	D	5.90	0.74	152.0	606	3
84	D	5.95	0.73	110.0	448	2
85	D	6.05	0.75	223.0	899	3
88	D	5.80	0.74	134.0	525	2
91	D	3.90	0.58	110.0	370	2
93	D	3.85	0.60	25.3	81	2
95	E	12.15	1.02	166.0	988	2
98	E	8.05	0.72	62.0	346	2
101	E	4.00	0.60	148.0	493	2
102	E	3.00	0.59	95.0	241	2?

$$\text{*Ult. strength per sq. in.} = \frac{\text{(Pressure in lbs. per sq. in.) (Mean diam. in inches.)}}{\text{2 (Mean thickness in inches.)}}$$

TABLE I.—Continued. RESULTS OF THE HYDROSTATIC TESTS.

Mark.	Class.	Mean diam. in inches.	Mean Thickness in inches.	Pressure in Lbs per sq. in.	*Ult. Strength per sq. in. in lbs.	Method employed.
103	E	2.25	0.63	160.0	286	2?
105	F	10.30	0.89	125.0	723	2
106	F	8.15	0.70	128.0	745	2?
107	F	6.20	0.72	166.0	714	2
109	G	12.00	1.06	22.0	124	2
112	G	11.90	1.05	12.0	68	3
114	G	10.35	0.99	30.0	156	2
116	G	10.05	0.97	52.0	269	2
124	G	5.90	0.76	130.0	507	2
126	G	5.95	0.76	110.0	436	3
131	G	3.90	0.68	105.0	301	2
134	H	11.95	1.03	143.5	833	3
136	H	12.00	1.07	115.0	645	3
137	H	12.05	1.05	153.0	877	3
140	H	9.95	0.91	152.0	832	3
143	H	7.85	0.87	153.0	690	3
146	H	8.05	0.90	91.0	407	3
147	H	8.00	0.92	94.5	411	3
148	H	6.00	0.78	185.0	712	3
149	H	6.00	0.78	143.5	552	3
150	H	6.05	0.76	257.0	1023	3
153	H	4.00	0.60	76.0	253	3
156	H	3.95	0.59	200.0	670+	3
157	H	4.10	0.61	223.0	749	3
158	I	4.05	0.70	170.0	492	3
164	I	6.45	0.78	94.5	390	3
165	I	6.25	0.77	120.0	487	3
166	I	6.15	0.71	124.0	537	3
171	I	10.10	1.10	128.0	587	3
175	I	12.45	1.08	46.8	269	3
177	I	12.35	1.13	42.3	231	3
185	J	6.00	0.86	94.5	329	3
193	J	8.00	0.82	94.5	461	3
195	J	10.00	0.83	62.5	329	3
197	J	10.00	0.88	128.0	727	3
200	J	12.00	1.08	124.0	689	3
202	J	12.00	1.07	134.0	751	3
206	K	8.10	0.83	59.0	288	3
207	K	8.20	0.89	78.0	359	3
209	K	4.20	0.51	223.0	918	3
213	K	5.90	0.78	178.0	673	3
214	K	7.95	0.86	115.0	532	3
225	K	12.05	1.09	139.0	768	3
227	K	11.90	1.14	143.5	793	3
236	K	18.15	1.39	81.0	529	3
242	K	4.45	1.45	85.0	628	3
244	K	20.90	1.89	90.0	497	3
247	K	24.00	2.02	185.0	1099	3

TABLE I.—Continued. RESULTS OF THE HYDROSTATIC TESTS.

Mark.	Class.	Mean diam. in inches,	Mean Thickness in inches.	Pressure in Lbs. per sq. in.	*Ult. Strength per sq. in. in lbs.	Method employed.
251	K	24.45	1.65	76.0	612	3
254	K	22.40	1.62	105.0	726	3
258	L	5.95	0.73	223.0	908	3
261	L	8.10	0.70	189.0	1093	3
264	L	12.05	1.09	170.0	939	3
266	M	4.00	0.60	295.0	983	3
267	M	5.95	0.72	265.0	1095	3
272	M	12.15	1.01	139.0	836	3
275	N	6.00	0.75	415.0	1660	3
277	N	10.00	1.00	365.0	1825	3
278	N	7.90	0.80	195.0	963	3
279	N	12.25	0.98	85.0	531	3
283	N	3.90	0.65	143.5	530	3
289	M	9.95	0.83	143.5	860	3
292	L	3.95	0.55	223.0	800	3
294	L	7.95	0.74	195.0	1047	3
295	L	10.15	0.86	143.5	847	3
315	P	12.05	1.16	71.0	368	3
316	P	12.00	1.16	37.3	192	3
318	P	12.05	0.99	90.0	547	3
319	P	11.90	0.94	52.3	331	3
324	P	9.85	0.84	72.0	416	3
331	P	7.85	0.81	165.0	800	3
333	P	7.80	0.80	159.0	775	3
334	P	7.85	0.81	149.0	722	3
337	P	6.05	0.66	171.0	1086	3
338	P	6.10	0.69	166.0	733	3

TABLE II. RESULTS OF THE DROP TESTS.

Mark.	Class.	Mean diam- in inches.	Mean thickness in inches.	Max. Fall of weight in inches.	No. of Blows.	† *Wv*	* *Wh*
16	B	12.10	1.08	12	4	144	18
20	B	9.80	0.92	12	3	144	18
26	B	8.20	0.86	12	5	144	18
33	B	6.15	0.79	18	8	177	27
39	B	5.05	0.64	12	2	144	18
41	B	4.15	0.69	18	8	177	27
44	B	4.15	0.68	24	3	204	36
47	C	12.15	1.11	12	3	144	18
52	C	8.00	0.91	18	12	177	27
*58	C	5.95	0.81	25	73	231	40

*In this case W equals 20 lbs.

† $W=$ 18 lbs. v = velocity of W in feet per second and h = the distance in feet passed through by the weight.

TABLE II.—Continued. RESULTS OF THE DROP TESTS.

Mark.	Class.	Mean diam. in inches.	Mean thickness in inches.	Max. fall of wt. in inches.	No. of Blows.	*Wv.*	*Wh.*
62	C	4.10	0.69	18	7	177	27
69	D	11.95	1.00	12	3	144	18
72	D	9.65	0.91	12	3	144	18
78	D	7.65	0.85	12	6	144	18
80	D	7.75	0.84	12	7	144	18
87	D	5.95	0.74	18	7	177	27
89	D	4.00	0.59	12	4	144	18
90	D	3.90	0.58	12	4	144	18
94	D	3.95	0.57	18	7	177	27
110	G	12.00	1.05	12	3	144	18
113	G	10.25	0.98	12	3	144	18
121	G	7.70	0.88	12	4	144	18
127	G	6.00	0.76	12	3	144	18
128	G	3.75	0.70	18	8	177	27
129	G	3.80	0.66	18	7	177	27
133	G	12.00	1.06	12	3	144	18
142	H	9.75	0.90	12	4	144	18
145	H	8.00	0.91	12	3	144	18
151	H	5.85	0.74	12	3	144	18
155	H	4.00	0.60	12	2	144	18
159	I	4.00	0.67	12	1	144	18
161	I	4.05	0.70	12	2	144	18
167	I	6.25	0.77	12	3	144	18
168	I	8.05	0.83	12	5	144	18
172	I	10.32	1.05	12	2	144	18
174	I	10.15	1.00	12	4	144	18
176	I	12.25	1.08	12	5	144	18
180	J	4.00	0.65	12	2	144	18
187	J	6.00	0.85	12	2	144	18
191	J	8.00	0.86	12	2	144	18
194	J	10.00	0.87	12	4	144	18
199	J	12.00	1.07	12	2	144	18
208	K	4.15	0.53	12	1	144	18
212	K	5.95	0.77	18	7	177	27
215	K	7.85	0.90	12	4	144	18
220	K	10.20	0.96	18	6	177	27
221	K	10.05	0.97	12	4	144	18
224	K	12.05	1.22	12	3	144	18
226	K	12.10	1.21	12	4	144	18
229	K	15.05	1.08	12	2	144	18
231	K	15.00	1.24	12	2	144	18
238	K	18.20	1.41	12	2	144	18
241	K	21.20	1.43	18	6	177	27
243	K	20.80	1.88	18	9	177	27
245	K	24.30	1.66	12	5	144	18
246	K	22.70	1.94	24	14	204	36
248	K	24.00	2.15	30	125	228	45
249	K	23.80	2.13	30	139	228	45
253	K	17.60	1.55	18	6	177	27

TABLE II.—CONTINUED.

Mark.	Class.	Mean diam. in inches.	Mean thickness in inches.	Max. fall of wt. in inches.	No. of Blows.	*Wr.*	*Wh.*
255	K	23.25	1.62	24	13	204	36
257	L	3.95	0.56	12	2	144	18
259	L	5.85	0.68	12	2	144	18
260	L	8.00	0.75	12	3	144	18
263	L	9.95	0.84	12	2	144	18
265	L	12.25	0.98	12	2	144	18
268	M	5.85	0.75	12	4	144	18
270	M	10.00	0.82	12	2	144	18
276	N	6.15	0.77	18	7	177	27
280	N	12.20	0.99	12	3	144	18
282	N	7.90	0.81	12	3	144	18
284	N	3.95	0.59	12	4	144	18
288	M	8.10	0.77	12	3	144	18
290	M	12.05	1.02	12	3	144	18
320	P	11.90	0.95	12	1	144	18
323	P	9.70	0.89	12	3	144	18
329	P	9.80	0.85	12	2	144	18
330	P	7.85	0.79	12	2	144	18
336	P	6.05	0.69	12	3	144	18

TABLE III.—RESULTS OF THE CONCENTRATED LOAD TESTS.

Mark.	Class.	Mean Diam. in inches.	Mean thickness in inches.	Cracked at. Pounds.	Broke at. Pounds.
19	B	12.00	1.08	1770	3465
22	B	9.85	0.93	2040	2040
28	B	8.15	0.81	2280	3180
30	B	6.15	0.81	3090	3750
36	B	5.05	0.63	3090	3090
42	B	4.15	0.69	4200	4200
49	C	12.10	1.12	3345	3975
56	C	5.95	0.82	1920	2205
60	C	4.05	0.68	4275	4275
66	D	12.00	1.00	2490	3975
82	D	7.65	0.83	3180	3180
86	D	5.95	0.73	3540	3540
111	G	12.05	1.65	2940	3345
115	G	10.30	0.99	1770	2370
119	G	7.70	0.85	2175	2175
122	G	7.75	0.87	2115	2115
135	H	12.10	1.10	2370	2490
138	H	9.85	0.92	2445	2490
144	H	8.00	0.90	2205	2925
154	H	3.90	0.57	3345	3345
163	I	6.35	0.76	1770	1770

TABLE III.—CONTINUED.

Mark.	Class.	Mean Diam. in inches.	Mean Thickness in inches.	Cracked at. Pounds.	Broke at. Pounds.
170	I	10.20	1.05	1515	2370
178	I	12.35	1.14	2490	2175
188	J	6.00	0.89	3225	3225
189	J	8.00	0.84	2490	2490
198	J	10.00	0.85	1500	1500
201	J	12.00	1.07	2490	2490
219	K	8.80	0.88	2640	2640
223	K	12.15	1.16	2910	2910
228	K	12.00	1.07	3300	3300
234	K	15.90	1.31	3300	3600
271	M	9.95	0.81	3150	3150
274	N	3.95	0.62	4875	4875
281	N	12.35	0.96	2490	2790
285	M	4.05	0.60	3750	3750
287	M	8.05	0.75	2670	2670
291	M	12.05	1.04	3180	3600
296	L	12.30	1.02	3480	3975
321	P	11.85	0.96	2670	2925
325	P	9.85	0.86	3225	3225
326	P	11.80	0.98	2490	2925

TABLE IV.—RESULTS OF THE UNIFORM LOAD TESTS.

Mark.	Class.	Mean Diam. in inches.	Mean Thickness in inches.	Cracked at.	Max. Load. Pounds.	Inches of Sand above Pipe.
54	C	8.00	0.90	4000	22500	1.50
74	D	9.70	0.92	2500	19500	2.00
125	G	6.00	0.75	13500	13500	4.00
132	G	3.95	0.69	15800	15800	7.00
152	H	6.00	0.78	7500	30000	4.00
160	I	4.00	0.69	14600	14600	6.00
169	I	8.10	0.88	3400	22500	4.00
173	I	10.25	1.04	3400	22500	1.75
179	I	12.35	1.09	3400	22500	0
186	J	6.00	0.86	12000	29300	2.25
190	J	8.00	0.86	4800	22500	4.00
196	J	10.00	0.87	2500	19500	1.75
210	K	4.05	0.53	13500	13500	6.00
211	K	5.85	0.80	10500	10500	4.50
216	K	7.85	0.90	7500	22500	4.00
222	K	10.05	0.98	5300	22500	2.75
256	L	3.85	0.56	18000	18000	7.00
262	L	10.00	0.87	7500	22500	2.50
273	N	4.00	0.61	24800	24800	6.00
286	M	5.95	0.73	18800	22500	5.00
293	L	6.05	0.67	10500	22500	5.00
314	P	12.10	1.14	6500	24000	2.00
332	P	7.80	0.82	9800	22500	3.50
335	P	6.10	0.69	13500	22500	5.00
340	P	6.10	0.68	9800	22500	5.00

TABLE V.—RESULTS OF THE CEMENT JOINT TESTS.

Mark.	Class.	Nominal diameter in inches.	Av. Thick. of cement joint in inches.	Av. depth of cement joint in inches.	Composition of Mortar.	Age of joint in days.	Pressure in pounds per Sq. In.	Method employed.	Remarks.
1&10	A	10	0.35	1.40	Neat Louisville B. D.	21	None.	1	1 broke.
2&3	A	8	0.35	1.50	" " "	41	50.0	2	2 & 3 broke
*4, 5&7	A	12	1.50	4.50	" " "	33	115.0	3	Joint leaked
8&11	A	6	0.26	1.40	" " "	33	148.0	2	8 broke
15&18	B	12	0.25	1.75	" " "	21	6.0	3	Joint failed
27&29	B	8	0.28	1.70	" " "	16	50.0	1	27&29 broke
31&34	B	6	0.44	1.65	1c. 2s. by wt.	14	None.	2	Joint failed
45&46	C	12	0.44	1.85	Neat Louisville B. D.	28	17.5	3	" "
51&53	C	8	0.50	1.80	" " "	21	None.	3	" "
55&57	C	6	0.34	1.80	1c. 2s. by wt.	14	None.	3	Pipes injr'd
77&79	D	8	0.27	1.78	Neat Louisville B. D.	21	17.5	3	Joint failed
83&85	D	6	0.34	1.63	" " "	21	25.0	3	" "
108&112	G	12	0.50	1.83	" " "	21	12.0	3	112 broke
123&126	G	6	0.34	1.75	" " "	21	17.5	3	123 "
143&147	H	8	0.56	1.90	1c. 1s. by wt.	6	12.0	3	Joint failed
148&150	H	6	0.30	1.80	" "	6	25.3	3	" "
†315&316	P	12	0.24	3.05	Neat Louisville B. D.	6	37.5	3	316 broke

*Ring joint. †Improved joint—bell and spigot grooved.

TABLE VI.

The Average Ultimate Tensile Strength in Pounds per Square Inch of the different sizes of Pipe of the different classes respectively. (Compiled from Table I.)

Class.	Method.	Ultimate Tensile Strength for the sizes given below.				
		4 in.	6 in.	8 in.	10 in.	12 in.
A	1					
	2		1—581	2—266	1—870	1—931
	3					3—814
B	1	1—399	1—284	1—142		
	2		2—476	2—243		
	3	1—596			1—775	2—547
C	1	2—476				
	2	1—457				1—391
	3			3—494		1—261
D	1			1—376		
	2	2—226	2—487		2—654	
	3		2—758	2—846		2—635
E	1					
	2	1—493		1—345		1—988
	3					
F	1					
	2		1—714	1—745	1—723	
	3					
G	1					
	2	1—301	1—504		2—213	1—124
	3		1—436			1—68
H	3	2—501	3—762	3—503	1—832	3—785
I	3	1—492	3—471		1—587	2—250
J	3		1—329	1—461	2—528	2—720
*K	3	1—918	1—673	3—393		2—781
L	3	1—800	1—908	2—1070	1—847	1—939
M	3	1—983	1—1095		1—860	1—836
N	3	1—430	1—1660	1—963	1—1825	1—531
P	3		3—877	3—766	1—416	4—360

* K 3 18in.—1—529. 21in.—3—617. 24in.—2—856.

NOTE. The figures on the left indicate the number of results combined.

TABLE VII.

The Average Tensile Strength in pounds per square inch of the pipes of different classes and tested by different methods. (Compiled from Table I.) Also the colors of the fractures corresponding to the greatest strength.

Class.		A	B	C	D	E	F	G	H	I	J	K	L	M	N	P
Average Tensile strength by method	1		245.8	476.0	376.0											
	2	582.8	359.5	424.0	455.7	470.8	727.3	271.0								
	3	814.0	616.3	435.8	744.7			252.0	665.3	427.4	547.7	647.7	939.0	943.5	1081.8	618.6
No. of results combined...		8	12	8	13	1	3	7	12	7	6	13	6	4	5	11
Average Tensile strength in lbs. per sq. in..........		669.5	407.2	442.9	582.9	470.8	727.3	265.6	665.3	427.4	547.7	647.7	939.0	943.5	1081.8	618.6
Color of fracture corresponding to greatest strength.		Chocolate Brown.	Fire Brick Yellow	Dark Stone Drab.	Dark Stone Drab.	Red'sh Brown.	Red'ish Brown.	Stone Drab.	Light Stone Drab.	Brick Red	Terra-cotta Red.	Dark Stone Drab.	Dark Red'ish Brown.	Dark Red'ish Brown.	Dark Red'ish Brown.	Dark Stone Drab.

TABLE VIII.

The Thicknesses of the various sizes of pipe under the assumption that the ultimate strength of the material is 600 pounds per square inch, that the pipes are subjected to a hydrostatic pressure of 100 pounds per square inch, and that the pipes are on the point of bursting.

Nominal diameter in inches,	2 in.	3 in.	4 in.	5 in.	6 in.	8 in.	10 in.	12 in.	18 in.	21 in.	24 in.
Thickness in inches..	0.16	0.25	0.33	0.42	0.50	0.66	0.83	1.00	1.50	1.75	2.00
Av. Thicknesses as m'fctured.	0.63	0.59	0.64	0.64	0.76	0.82	0.90	1.05	1.39	*1.89	*2.02

*Extra heavy.

TABLE IX.

The average ultimate strength in pounds per square inch of the different sizes of pipe. (Compiled from Table I.)

Nominal diameter in inches.		4 in.	6 in.	8 in.	10 in.	12 in.	18 in.	21 in.	24 in.
Method.....	1	450.3	289.0	259.0					
	2	340.6	532.1	351.5	554.5	608.5			
	3	652.6	761.0	651.3	799.8	589.5	529.0	617.0	856.0
General average of methods 1, 2 & 3		517.2	677.8	551.9	701.7	592.1	529.0	617.0	856.0
No. of results combined..........		16	25	26	15	29	1	3	2

AN ENLARGED WATERWAY BETWEEN THE GREAT LAKES AND THE ATLANTIC SEABOARD.

DISCUSSION.

(*Continued from page 193.*)

By L. E. Cooley.

The Society and the public are indebted to Mr. Corthell, for bringing so prominently to the front, the project for direct marine connection between the Great Lakes and the Atlantic Seaboard. The idea of seaports in the interior of the continent, from which commerce may be carried on to all parts of the world without breaking cargo, is one of great promise to the future of lake cities and, to a certain extent, revolutionary of the transportation problem of the country.

The Continental Waterway.

In former presentations, I have developed the idea of a waterway of the largest proportions by the lowest continental line, from the Atlantic via the Great Lakes and the Mississippi to the Gulf of Mexico. Such a waterway would join as a whole and make tributary all the interior water systems of the continent, would pass through the productive heart, and be accessible from the entire coast line. We have only to study the census returns and the location of our commercial cities in regard to waterways, to understand what such an achievement would mean to the country at large. We have only to note the position of Chicago at the summit of the only possible pass between the Great Lakes and the Mississippi valley, to realize how paramount to all other cities is the interest of Chicago in any project for deep water, either to the Atlantic or to the Gulf of Mexico.

This general project lies well within the possibilities of achievement and the resources of the country, and no deep study of economic questions is required to make it apparent that it is worth all that it can possibly cost. There is, however, a radical difference in the character of the problem in its two parts, a difference in the treatment required from the lakes eastward to that demanded from the lakes southward.

To the eastward we have streams of permanent regimen, the descents are precipitous and in rock bound rapids or over falls. The passages through which water routes may be led are well defined and stable. Within certain maximum limits of capacity, works can be exactly designed and estimated and results achieved at once, or as fast as the resources are made available. No uncertainty is felt as to the length of time required to accomplish a given object.

These characteristics apply to the southern route over the rock bound section to Utica, one hundred miles from Chicago, and this limit may be extended over a different character of river to the mouth of the Illinois, 225 miles further, and possibly to St. Louis. In the Mississippi, however,

results are to be obtained progressively and involve a large element of time. Beyond certain limits of depth, an increase in the low water volume is demanded. This may be obtained through a systematic construction of reservoirs at head waters and by drawing on the Great Lakes. With these aids, any limit that may be set for the route eastward, may be regarded as an ultimate possibility to the south, for a period as long at least as the lakes are free from ice. The object is attained as a result of a systematic policy rather than by the specific execution of special structures.

It by no means follows that what may be immediately achieved is not valuable or justifiable. If fourteen feet of water existed through the Illinois to-day, boats drawing ten to twelve feet could go through the Mississippi for about seven months, or a period equal to that of lake navigation. The improvement upon which the Mississippi River Commission are engaged, would probably be so far advanced by the time the works at this end could be completed, that fourteen feet could be carried through for the full period of lake navigation. So the immediate achievement may contemplate fourteen feet to the Gulf, or as much as that for which the Canadian canal system is designed from Lake Erie to Montreal. The policy should, however, be set to a still higher gauge for the future.

As to the immediate achievement of such a result, a careful consideration shows that the cost of making a large channel across the Chicago Divide, some forty miles to Lake Joliet, sufficient in depth for a harboı and of capacity for a large volume of water, will not differ greatly from the cost of carrying a depth of fourteen feet from Lake Joliet for 285 miles to the Mississippi; in other words, one-halt the cost of the route for 325 miles through the State of Illinois, between Lake Michigan and the Mississippi, is in the first forty miles.

The several routes which may be selected from the lakes to the Atlantic will be closed by ice from four to five months, according to the location, or navigation will be open from seven to eight months. The route southward will be closed from two to three months (an average of about 75 days at Morris, Ill.,) or open to navigation from nine to ten months. This is an advantage of about two months over the eastern outlet, an advantage that grows more marked toward the south, the closing at St. Louis averaging but one month. The facilities thus presented for vessels to leave the lakes at the beginning of winter and to return in the spring, are most marked over the eastern route which practically closes throughout simultaneously. For the past two years, the southern route would not have been closed at all.

The public mind has been so persistently misled by statements of the minimum depths in the Mississippi, as though they were the boating depths, that doubts havs been awakened against the possibilities of the southern route. The minimum, or low water depths, of southern rivers, prevail for a fraction of each year, usually less than northern streams and lakes are frozen up, and in some years are wholly absent. The minimum depths of the Mississippi, as unimproved from St. Louis southward, are from four to six feet, while the draft of fully loaded barges and steam-

boats in which over three-fourths the commerce of St. Louis southward is carried, is nine to ten and a half feet, and this is really the available depth for navigation. The present project contemplates a minimum depth of ten feet, or a boating depth of fourteen to sixteen feet, for a period comparable with lake navigation.

The two projects, a water route south as well as the one to the east, are really parts of one general project, from a Chicago standpoint. To that part of the southern project which provides a deep channel across the Chicago Divide, we must work for the development of a harbor, if Chicago is to maintain her supremacy as a deep water port and profit through a connection with the sea.

Future Lake Commerce and Freight Rates.

Mr. Corthell has presented the physical features of the several eastern routes and dwelt upon the magnitude of the lake marine, so fully, that little need be said by way of information. The significant fact is, that the number of tons carried one mile upon the lakes is 22.6 per cent. of the ton-mileage of all the railways in the country. If the movement through the New York canals and upon the Hudson and St. Lawrence rivers were included, it would probably not be far from thirty per cent.

I am prepared to believe that were the lakes connected by deep water with the ocean and our seaboard cities, that the movement would be fully fifty per cent. of the ton-mileage of all the railways, so great are the advantages of long routes to water carriage; and that the longer season and new class of commodities of the southern route. would largely increase this proportion.

The available depth for lake navigation is sixteen feet, obtained in 1874, at the St. Clair Flats, and in 1881-3, into Lake Superior. The original depth through these obstructions was but nine to ten feet. Upon these depths, the largest boats carry three thousand tons of cargo. The average rate for all carriers was 1½ mills per ton mile in 1889. A very large amount of freight in coal, ore and grain, was carried for one mill and under, and this is at about the rate at which the line boats on the longer routes pro-rate with the railways in through shipments by Lake Erie ports, or on the basis of five to seven mills per ton-mile for the railways.

The improvements between Lake Huron and Lake Erie, and through the St. Mary's river and canal into Lake Superior, are now being prosecuted on a basis of twenty feet.* The Niagara Ship canal is projected on the same basis, and this may be regarded as the present fixed policy for lake depths. Within five years, vessels of a draft of twenty feet are to be expected and boats of this draft will carry over four thousand tons of cargo, or an increase of over one-third over the present largest type of boat. It is probable that such boats will carry bulk cargoes on long routes at not over three-fourths mill per ton-mile, or fifty per cent. in

*The recent lake craft are modeled so as to load to twenty feet when it is obtained, but are actually restricted in their carrying capacity to the depth of harbors or about sixteen feet.

excess of ocean rates, and that the general movement about the lakes will not exceed one mill.

For the reasons given, I regard the rate of 1½ mills per ton mile, as compared to through shipments by rail to seaboard points on the basis of five mills, as too high, and estimate one mill as high enough for general commerce of lake routes, or one-fifth the rail rate, under the conditions which will soon obtain. Special commodities and longer distance will make it still lower.

In computing the cost of transportation, Mr. Corthell has added interest, maintenance and operation. This may be proper in comparing different projects, but in this country, the time is certainly passed when such works are to be built, maintained and operated at the direct expense of commerce. The policy of regarding them as free highways, to be provided at the general expense, is too well settled to admit of change. If any justification is needed for such works, it is fully furnished in those statements of the paper which show that the freight savings of one year are sufficient to cover the entire cost. It will not be legitimate to add anything to rates for such works, except as they are sources of delay in the movement of boats.

It is to be observed in passing, however, that a large proportion of the movement by lake would not occur at all by land, or without water transportation, and in this view the water route is a contributor to commerce rather than a rival of the railways. Out of the fuller prosperity, the railway probably reaps a better reward, and this judgment is borne out by the prosperity of railways that are apparent rivals of water routes.

It is well known that freight rates are relatively less on longer routes, which may be ascribed to something in the nature of a fixed charge at terminals. Most of the bulk freight routes on which low charges prevail, are from six hundred to nine hundred miles, and may be designated as three day routes. Allowing two days in port at each terminal,* a round trip on such routes consumes ten days. Suppose the route is extended from Lake Erie to tide-water at Montreal or New York, by the best waterway improvements that it may be feasible to construct, then it appears that the round trip will be increased to say fourteen days for Montreal, and sixteen days to New York, or very nearly in the ratio of the increased distance. The cost to tide-water will then be enhanced nearly in proportion to the additional distance. This assumes that the cost per day in port is the same as en route, which is approximately true.

Without going farther into details, it appears that the mill rate for future navigation of twenty feet can be carried to seaboard points. From Chicago to Buffalo, this would be 90 cents per ton, and to Montreal $1.26, and to New York $1.44, on the basis of the round trip time given, which is almost directly in proportion to the distance. Farther than seaboard points, these results would not follow, as the delays on the restricted channels from the lakes to the coast would not offset the advantages of longer carriage. On through cargoes to foreign ports, the charge would be

*It is usually longer at Chicago.

relatively less per ton mile. Certainly, if the mill rate is to obtain on the high seas, it will pay to tranship to a less expensive type of carrier at the seaboard, and this may be what Mr. Corthell contemplates in his estimate of a half mill rate for ocean carriage.*

It is apparent that the completion of the St. Lawrence canal system on a basis of a draft of fourteen feet, will not avoid transhipment at Port Colborne and Montreal on foreign shipments, or even on domestic shipments over long routes from the lakes to Montreal and the St. Lawrence and lower coast. It will afford direct passage for a coasting business over shorter routes and between the shoaler harbors. It will probably be a cheaper route than the Erie canal; though the doubling of the length of locks, their widening to twenty feet and the increase of depth to eight feet, improvements now in progress, thus enabling a boat and consort under steam, and with one crew to carry some seven hundred tons in place of a present limit of two hundred and forty tons,—will largely diminish the cost of movement. Considering the tremendous movement to the great cities of the American seaboard, along established traffic lines, and the disadvantageous position of the St. Lawrence in relation to these determined points of commerce, it seems probable that the Erie canal will continue to hold its own against the improvements of the St. Lawrence now in progress.

The Ultimate Depth for Lake Commerce to the Seaboard.

A great channel and of the full depth for which the lakes may be improved, will profoundly affect commercial movement. Experience has shown that the economical carrier must increase in tonnage with the longer route. The length of route on the lakes demands a type of boat which is occasioning an increase of depth to twenty feet. When this route is extended to the seaboard and to foreign ports, an argument is made for larger depth, greater even than that which now obtains for the high seas. It is germane, therefore, to consider what may be the attainable limit for future lake navigation, and to so design the improvement that present works for twenty feet may be readily increased. This policy need not add greatly to the immediate expenditure, but will materially influence the design, thus requiring much forethought, careful consideration, and the fullest data.

From such study as I have been able to give the subject, twenty-four to twenty-five feet at low water, represents the limit of future achievement about the great lakes. Such a depth will demand extraordinary improvements, costing much money. It is doubtful whether these limits could ever be practically exceeded, as the depth is so large a proportion of what actually obtains in straits and rivers, and even in some portions of the lakes themselves, and demands improvements over such extended reaches, that any increase in draft of boats above this limit, would so restrict the freedom of movement and the speed, as to probably increase

*A rate of three-fourths mills for the lake and seaboard would probably be nearer future conditions, corresponding to one-half mill for the high seas. Even now cargoes are carried at this rate.

the actual cost of transportation. It is a depth, however, that would accommodate a good class of line boats to tide-water and foreign ports, and be sufficient for the best class of ocean tramp. Adhering to our lake models, with such modifications as sea experience may demand, the future carrier would range in capacity from four to five thousand tons of cargo and might approach six thousand tons.

Under these conditions, rates would probably be under three-fourths mill per ton mile for lake and tide-water commerce, and future movement between lake-board and seaboard would probably be less than one dollar per ton. The movement to European ports would probably not exceed one-half mill per ton mile or about two dollars per ton from lake to European ports. That in the event of deep water to the Atlantic, a policy looking to an ultimate depth of twenty-four or twenty-five feet is expedient, I do not doubt.

Commercial Considerations Determine Route to Atlantic Seaboard.

Commercial considerations are more largely determinative of route than engineering ones. It is not a question solely of the cheapest line, but where the line will accommodate the most traffic in proportion to the expenditure. If a line across New York to the Hudson, reaching directly the great Atlantic seaboard from Portland to Norfolk, will be of direct service to several times the commerce of the St. Lawrence route, then in that ratio is a greater expenditure justified on such a route. I can conceive of a feasible project for deep water to the Hudson by the Mohawk valley, and of an inside route from Chesapeake Bay and Baltimore via Philadelphia and the Delaware to New York Bay and thence by the Sound and Cape Cod to Boston. I hope sometime to present a project from the lakes to the Hudson, via the Mohawk valley.

Some statements in support of this view, may be of interest.

It has been already developed that the present commerce of the lakes much exceeds the entire foreign movement. It may also be shown that the movement from the interior to the seaboard, from Portland to Norfolk, is many times the foreign movement. It is a conclusion borne out by experience, that the foreign movement will follow the lines of maximum domestic traffic, and can be most cheaply handled in these directions. The domestic demand is comparatively uniform, and will remain the controlling factor in commercial movement. Without going into this subject at length, it appears to me that a route to the ocean will be disappointing if it does not reach the American seaboard and accommodate the domestic as well as the foreign trade. In fact, have we not the example of four or five times the traffic along the Erie canal and the Hudson, notwithstanding the present superior facilities of the St. Lawrence route.

A similar line of thought makes Lake Erie a necessary part of any such route. It dips down deep into the heart of the country, west of the Allegheny mountains, and draws to itself an immense traffic from the country south, and is the present terminus of nearly all lake routes and their railway connections, with a commerce greater than any other lake. It

is doubtful if the Ottawa or Hurontario route can greatly change its position of advantage.

This chain of reasoning determines the route by Lake Erie, Niagara Falls and Ontario, and thence to the Hudson, and I should favor this route even if it should lead for the present, down the St. Lawrence to Lake St. Louis, within ten miles of Montreal, and thence by the Caughnawaga canal, Lake Champlain and the Upper Hudson.

I believe that the practical test would show several times the commerce passing by this line, as compared to that stopping at Montreal. If it did not go this way, it could only reach its destination by transhipment at Lake Erie ports and Oswego, as now, or else take a coasting trip of about two thousand miles, from Montreal to the American seaboard.*

If we could suppose such a route developed to-day, it would reach by a circuitous line all the great traffic centers naturally tributary to this water route, and without prejudice to any interests of commerce. Even on the longest development, the project can be shown to be enormously profitable as a measure of economics. As traffic develops to those great proportions which will sometime make the wisest provisions inadequate, we can develope new routes on the shorter lines for the through movement, without prejudice to any part of the system, leaving the older works to serve the needs of the territory, outlying in their direction.

Taking the time of a round trip from Michigan and Superior ports via Lake Erie to Montreal at fourteen days, we cannot at best hope to save over two days, or one-seventh, by the Ottawa, Hurontario or Michigan peninsula routes, and it is probable that the money required to develope these cut-offs, if systematically applied to better depths and better facilities on the main line, would effect a greater reduction in the through rate of transportation and avoid side-tracking any of the lakes. When the best has been had by this line, then the shorter routes may more properly come in. Such a policy also enlists every interest.

A project can be made that will enable commerce between lake and tidal points, to be carried on for one dollar per ton or less. What the magnitude of that commerce would be, no man can predict. We have seen an absolute growth of commerce into Lake Superior of eight million tons in ten years. We have about seven million tons of movement on the Erie Canal system and the St. Lawrence. I believe that within ten years after deep water is opened to the American coast, the movement will not be less than twenty million tons, and if that movement is restricted to the St. Lawrence, it will not exceed five million tons in the same time. We may assume a saving over rail shipments of three dollars per ton, but limiting it to two dollars, it represents not less than forty million dollars annually.

Although the influence on rail rates everywhere would be very great and although it would carry large quantities of competitive freight, still we must look to such a water route as developing most largely a commerce

*To tide-water at Albany by the Champlain route, is only 227 miles farther than to Montreal.

which might not otherwise exist, as a contributor to our material resources. From this point of view, the argument is greatly strengthened.

If the position is well taken, then the matter of cost is not important and we can best afford to develope that line which will best serve the needs of commerce. The saving to the country, even on the basis of forty millions per year, is vastly in excess of what any proper project can possibly cost.

The Project is International.

I can agree with Mr. Corthell, that the problem cannot be hemmed in by artificial boundary lines. Nature did not fashion the continent with a view to such limits, and the solution of the problem is a contribution to nature and an addition to the resources of the continent. Among a kindred people drawing prosperity from the same commercial resources, statesmanship should be broad enough to make the most logical interpretation of the physical and commercial conditions. Such a water-way achievement would of necessity cement one commercial entity and lead ultimately to political union.

It seems to me that the physical and commercial conditions dictate the first development of a route, by Lake Erie, Niagara, Lake Ontario, the St. Lawrence and Lake Champlain, reaching both the St. Lawrence at Montreal and the Hudson at Troy. When this route has developed sufficient commerce to justify it, a cut-off may follow by the Mohawk line and later by the Ottawa, rather than the Hurontario. These would all be water lines except the Hurontario, for which a ship railway is the best solution.

Gen. Poe has recently submitted an estimate of $3,340,000 for completing the work of obtaining twenty feet of water between the Great Lakes.

Mr. Corthell estimates $52,000,000 as required to carry this depth from Lake Erie to Montreal, $17,000,000 of which is for the St. Lawrence.

The total for twenty feet of water between the lakes and for connecting the same with an ocean navigation of twenty-seven feet at Montreal is therefore $55,340,000.

In 1875, an estimate of $19,651,000 was made for carrying twelve feet of water from Lake St. Louis, nine miles above Montreal, to tide-water of the Hudson at Albany, the project being the continuation of the Enlarged Welland.* An approximate estimate for twenty feet can be made from this old data and from the coast survey charts of Lake Champlain and of the Hudson River, on the basis of the works proposed by Mr. Corthell for the Niagara Canal and the St. Lawrence improvement.

The works will be as follows:—

	To be Improved.
Canal: Caugnawaga Canal from Lake St. Louis to Richelieu river at St. Johns,—lockage 29 ft......	32 miles.
Lake and River: Richelieu River and Lake Champlain from St. Johns to Whitehall, 133 miles, of which Richelieu must be deepened for 17 miles	

*The depth of the Welland was subsequently made fourteen feet.

and Lake Champlain for 16 miles	33 "
Canal: Whitehall to Fort Edward, on upper Hudson,—lockage 66 ft	24 "
Canalized River: Upper Hudson to Troy dam, head of tide,—lockage 118 ft	40 "
River: Hudson to be deepened	26 "

This work should cost inside the following:—

56 miles of canal and 95 ft. of lockage	$27,000,000
40 miles canalized river and 118 ft. of lockage	15,000,000
59 miles of river and lake to ample width	9,000,000
Total to be improved, 155 miles	$51,000,000

The total for twenty feet of water to the American seaboard is, say, one hundred to one hundred and ten million dollars, or less than the capital account (stocks and bonds) of any trunk line from Chicago to the coast. The making of Lake Champlain a part of the system, with 133 miles of length from St. Johns to Whitehall, adds decidedly to its merits.

Chicago's Position.

The interest of Chicago is paramount, for here centers the largest commerce of the Great Lakes. She may place herself in position to hold and increase her supremacy by a great water route to the South and West, an artery of supply from the Mississippi Valley that is not feasible to any rival port.

Chicago is, however, in most miserable position to profit by a great water route. Her harbor is only available for vessels of a draft of fourteen to sixteen feet, and to accommodate vessels of twenty feet and over, a new harbor must be created, as the present one offers insuperable difficulties to development. Already, charges at this port for some commodities exceed those at rival ports.*

The economic bearing of the harbor problem, I have discussed within the past year, in a report on "The Lakes and Gulf Waterway as related to the Chicago Sanitary Problem."

The proper solution of the harbor question may grow out of the sanitary problem. It should do so and without increase of burden to this people. Otherwise, in the near future, we may find ourselves contemplating millions of expenditure, only comparable to Manchester, to maintain the marine supremacy of our port. This is the second port on this continent, with a marine movement vastly exceeding that through the Suez Canal and nearly equal to the estimate for the Manchester ship canal. This marine commerce is largely terminal and if we eliminate through consignments by railway, probably represents one-third the total local consignments and shipments. These facts should make Chicago realize what the loss of marine supremacy may mean.

*It is estimated that charges for towing aggregate over $300,000 yearly. Some of the larger vessels when loaded have consumed over six hours in getting out of the river. A proper harbor would save a large proportion of the towing and the time spent in port.

Deep water to the Atlantic and Gulf seaboards, and harbor facilities by which she may reap every advantage, should be the policy of Chicago.

If I have seemed to differ with Mr. Corthell, I ask your consideration, for he may be right. In any event, discussion marks the progress of education.

BY T. T. JOHNSTON.

I had intended to collect in proper form some data bearing on the relation of a transportation route to the changing habits of the people, but have not had time to do so. The thought was suggested by some studies of population changes in Illinois, which show a decrease of rural population during the past 20 years, while city growth has rapidly increased. This means that more things are made per capita of population than formerly, and this is still the tendency of the times. People are concentrating at remote centers with the result that larger volumes of stuff are to be transferred from any given point.

This tendency of the times is in a direction to require not only more transportation facilities, but to require a greater capacity for carrying freight in bulk.

If a large water-way was useful twenty years ago, then it is more than doubly useful now, if its usefulness can be measured by the tendency of people to concentrate at a locality.

It may astonish some to know that the rural districts east of the Mississippi and north of the Ohio have been over-populated for about 20 years past, and have been steadily falling off in number of inhabitants.

Another feature of this tendency to change of occupation of people is to render public works useful in furnishing employment. A country that has more people than are needed to furnish and create the necessaries of life needs something for the surplus population to do.

BY E. L. CORTHELL.

As the original paper and the discussions that have followed have already assumed considerable length, the author by permission will briefly discuss the salient features of the papers that have so far appeared during the discussion.

Mr. Bates, with a wide experience on public works, approves the paper and the proposition, and the author only desires to quote a part of the last paragraph to show his hearty accord with the views advanced by Mr. Bates: "Such a waterway would be a blessing to both countries and the direct and indirect advantages which would accrue to the citizens of each invite the cordial cooperation of the respective governments. It should form a bond of union between the two greatest nations and is a step towards that time when all nations shall be at peace."

Mr. Day brings to the discussion a large experience in commercial matters and an intimate knowledge from professional experience in naval architecture in Europe and, as usual with the experienced and skillful naval architects and dock builders of Europe, he entirely approves the new

method of transportation by Ship Railway which is just now coming into actual practice.

The best talent of Great Britain has approved the general principle of carrying ships on a railroad where the conditions make it advisable to do so and commerce is benefitted thereby.

The author would gladly accede to the request of Mr. Day, after the favorable discussion given by him, and bring forward the dimensions and plans of a ship railway for the various routes which have been suggested between the great Lakes and the Seaboard, but he must ask the Society to assume at present the entire practicability of this method until at some subsequent time he, or some one perhaps better fitted, shall write in detail on this important subject.

The discussion of Mr. Marx, being generally in accord with the views expressed by the author, requires only a brief notice where in the closing paragraph the question is raised as to the various routes through Canada to be built by the Canadian Government under its auspices.

It is merely an opinion, but still quite well grounded, that the Dominion Government will be slow to raise an appropriation of 83 million dollars for the building of any internal improvements like the Ottawa eadal. A country of five million people, with a heavy financial burden already on their shoulders, will not readily consent to the imposition of such a tax when a commercial route of much greater advantage can be obtained for much less money, and especially if that be raised, not by tax, but by guaranteed interest: and the further opinion is advanced that the Hurontario & St. Lawrence route is all that Canada will desire when all the facts are placed before it.

In opening the discussion on the paper of Mr. Williams the author expresses his great regret that the details, which appeared in the paper read before the Canadian Society, were not fully given in that presented to the Western Society, so that Mr. Williams might not have been obliged to go to such an extent in attempts to controvert many of the summarized facts given in the author's abstract of his paper.

While the patriotism of the author is not questioned, yet it is intimated that the influence of his professional brethren of the Canadian Society had something to do with bringing forward the suggestions that a route through Canada would be preferable to one through the United States. The author endeavored in his paper before the Canadian Society, and also in his abstract before this Society, to make it plain that in his treatment of this important commercial subject, he had ignored entirely the arbitrary boundary lines which cross and otherwise obstruct the natural channel to the Seaboard, and which prevent, when their influence is present, the holding of statesmanlike views on this great question.

The author, in prefacing tne reading of his paper before this Society, read a letter from the President to a prominent man of Chicago, in which the principle which should govern us was convincingly stated in the following language: "The question of patriotism may be raised in considering the route which may possibly pass through foreign territory. I have preferred to take the ground that this Continent is one people and will at no

distant day be in one political Union, at least so far as our northern neighbors are concerned, and I have preferred to think that we can afford to ignore fictitious boundaries and promote such a project, even though it should lead through Dominion territory, though as surely as a great waterway is developed from the St. Lawrence to the Mexican Gulf it will link the people of the two continents in bonds closer than mere treaties can formulate."

Mr. Williams takes exceptions to the Hurontario route for the reason that it would leave the cities on Lake Erie and the Detroit river off the Seaboard route. There is no question in the author's mind about the certainty of a ship railway in the near future being built on the United States side of the river between Lake Erie and Lake Ontario, but for the main purpose which the author had in view, namely, to investigate and to propose a through route for the commerce of Lake Michigan and Lake Superior,—Chicago and Duluth to Liverpool,—the shortest and most direct route, assuming it to be a practicable one, was necessarily recommended by him. However he would promote, in all proper ways, the building of an adequate connection between the two lower Lakes for the benefit of the great commercial cities along the south coast of Lake Erie.

In order that it may be clear that the Hurontario route, even if devoted to the transportation of through freight alone, will have sufficient business to pay for its construction, maintenance and operation and the improvement of the Lakes and river, the author will offer here some important facts and a strong argument for that route presented by the Hon. D. Blain, of Toronto, Can., before the Toronto Branch of the Can. Soc. of Civil Engineers, when the author's paper was under discussion: "It is impossible to do more than glance at the probable volume of freight that would pass over this road. The Eastern States require about 300,000,000 bushels of grain to supply their wants, nearly the whole of which has to be carried from the West to the East. Then the manufactured articles have to be taken west in return. No considerable part of either is by the United States imported from abroad. Nearly all is raised in the west or manufactured in the east. Great Britain requires about 250,000,000 bushels annually and her demands are daily increasing. All countries exporting grain compete in the English markets. This Continent within the influence of the Lakes could supply the greater part of this demand, if satisfactory carrying facilities were afforded. There is abundance of free land easily brought under cultivation that produces large averages of the best grain on the markets. All the labor can be done by machines so cheap that hand labor cannot compete with it. The great want, the call for which has now reached a wail, is increased facilities for carrying the farmers' products at reduced rates to the markets. Of late we have greatly improved in this respect, as heavy freight charges are not one-half now what they were twenty years ago. Every seaport town in Britain can be supplied with staple farm products raised thousands of miles away for less than the English farmer can cart his surplus to the same place 20 or 30 miles distance. If accurate returns were available it might appear that

the Lake trade has now reached 40,000,000 tons annually and is daily increasing. At the point in Lake Huron which has been described as the proper beginning of the Hurontario route there passes not less than 25,000,000 tons of freight yearly. The Sault and Chicago alone send on about 20,000,000 tons. This point is only 3770 statute miles from Liverpool or 350 further than New York City. From this point under favorable conditions such as can be easily obtained, freight can be profitably carried to Liverpool for $2.66 per ton or about 8 cents per bushel for wheat; while by rail from Chicago to New York it costs $6.74 or over 20 cents per bushel delivered in Liverpool. If the North West supplied Britain with 100,000,000 bushels which it could easily do there would be an annual saving on this item alone of $12,000.000. The saving on this single item in four years would more than pay for the entire cost of the works from the tide water to the head of the Lakes. If 8,000,000 tons of freight were carried through to the journey's end the saving in one season and a half would meet the entire outlay.

If the 8,000.000 tons contemplated by Mr. Corthell passed over this road taking the average charge established by the Interstate commerce commission of the U. S. for carrying freights the income would be $4,940.000 annually. At the rate Mr. Corthell adopts half a cent per ton per mile the annual income would be $2,640,000 annually. By this route the shipper for the ordinary charges, or less, would save the entire increased distance by the Welland route, as well as the time without paying a single cent for these advantages. If this road were constructed it must command the trade. The trade in this case means the great volume of freights moving from west to east and from east to west along the great artery from the Seaboard to the Centre of North America and return."

Referring for a moment to those paragraphs in the discussion of Mr. Williams in which he endeavors to show the inconsistency of the author's figures, particularly in regard to cost and rates of transportation by the various routes and methods, it is only fair to say that out of the varied and conflicting mass of figures which are given in the rate tables by lake, river, canal and ocean between various points, some of them great commercial centres and competing points, and taking the tables even between the same points in different years, it is almost impossible that two students of the subject should agree even on the main point. The author was unwilling to invent or to predict rates for the future conditions, and for the purposes of comparison considered it wisest to take the average rates as they are. If he has erred at all it is in taking the least feasible rates instead of the average rates. The ocean rate for a 24 to 25 foot draft by steamer is ½ mill per ton per mile, but the average rate would be 1 mill. The least feasible rates on the Lakes with from 14 to 16 foot draft is about 1 2-10 mills, although large steamers with barges in tow can transport grain at 9-10 mill, but the average rate is over 1½ mills, and even these rates are for a special class of freight; and merchandise freight is much higher. The author, also for the purposes of comparison of the rates, assumed that Montreal was a point where possibly it would be found necessary to change from a 20 foot draft vessel to a 25 or 26 foot draft and

that the distances of the two routes would then be as about 1000 to 3000 to Liverpool. The author has recently ascertained the rates for long distances between New Orleans and Liverpool, 5528 miles, and finds that the cotton rate for 1889 and 1890 was nearly 3 mills, oil cake and meal $1^2/_{10}$ mill, grain at 5c per bushel—$1^6/_{10}$ mill. Between New Orleans and New York, over which route in large steamers carrying from 3500 to 5000 tons, probably 80 to 90 per cent of the transcontinental business of the country goes, the rate of first-class freight is about 6 mills per ton per mile; 5th class 3½ mills, special 2½ mills while cotton and sugar on this route, about 2000 miles in length, is handled for a little less than three mills.

The author therefore prefers to leave his figures as they are and let the actual transportation in deep draft vessels from Chicago to Montreal or from Chicago to Liverpool, if practicable, determine the rate. In the comparison which the author made of the cost of transportation over the various routes he did not consider, as Mr. Williams states he did, that the St. Lawrence canals would be free and desired to place them on the same basis as the other routes, making the rate on the basis of cost of operation and interest on the cost of construction, and what seem to be anomalies in the rates per ton hauled over the ship railways and ship canals, are fair and correct estimates of what the rates would be on the same basis as that of the St. Lawrence Canals. The reasons for the seeming anomalies are, first, the cost of the canals and of course the interest is in every case greatly in excess of the cost and interest of the ship railways, and the cost of maintenance and operation is also, in every instance, greater in the case of the canals. The author also asserts that it costs more to push vessels through the restricted channels of ship canals than it does to haul freight on an ordinary railway and that it costs *a great deal more* to transport freight on a barge canal than it does on an ordinary railway, that is the best railways. This assertion is capable of detailed proof which the author will be glad to give in a paper on this special subject at some future time and in that paper he will show that the fact of the cost of transportation on a ship railway is but 3 mills per ton per mile, whereas it is 5 mills on an ordinary railroad, is due to conditions which anyone will readily see and appreciate when brought forward, and that it is not, as Mr. Williams states, a proof that ordinary railways are operated on a wrong system, but that ship railways are operated on a better system, conducing to still greater economy than the railroad itself has brought about by moving in the direction of such a method of transportation as the ship railway will bring, namely, in hauling great masses of freight and avoiding handling at terminals or at points where the ship railway, as at Georgian Bay, will form a link or a bridge between two great bodies of water.

It is a fallacy also to assert that the Erie Canal is holding its own, which seems to be intimated, if not stated, in the papers of Mr. Williams and Mr. Cooley. The Erie Canal carries a million tons less freight now than it did in 1868, 23 years ago, whereas the three railroads, which are the competitors of the canal, have increased their tonnage five-fold. The Erie

Canal would not be in existence to-day, (except that its bed might possibly be a roadbed for rails) had not the State of New York removing first its tolls and then assuming the cost of maintenance and operation, left the canal boats with no expense except the wages of a boy and the food of a mule. To compare such a method as this, with comparatively no expense in the operation, with the great and convenient facilities of the railroads that parallel it is absurd. To refer to details again for a moment, the running expenses of the Erie Canal are about *one mill* per ton per mile on freight hauled by steam canal boats with consort, the least expensive working. The cost of hauling freight on a first-class railroad, to cover practically the same items, namely, cost of fuel, stores, train hands, and repairs to locomotives is $^6/_{10}$ *mills*, and in order that there may not seem to be, as Mr. Williams intimates, any anomaly in the statement that ship railways will haul freight at less cost than ordinary railroads, let us make a comparison: The entire cost of moving freight on a well built and properly managed railroad in this country is not over 3 mills per ton per mile, but this cost includes numerous and expensive handling of goods and local as well as through freights. The cost of handling is about the same as the cost of hauling for distances up to 100 miles. From this we can see the immense advantage that ship railways would have over the ordinary railways in such locations as that of the Hurontario ship railway where there is no handling, the hatchways are not even opened. Then again there are more goods carried at one time, thus economising time and labor. Instead of a car carrying 15 to 20 tons we have a car carrying 1500 to 3000 tons.

The only obstacle to the introduction to the world of the vastly superior method of transportation by ship railways is its novelty. Just such an obstacle delayed the introduction of the steam engine, the steam boat, the locomotive, the iron steamship, the telegraph, the ocean cable and many other great inventions now universally adopted and no longer wonders.

The construction of one ship railway on a large scale will lead to the building of many more as at the Huron Peninsula, Niagara Falls, the American Isthmus, across the Florida Peninsula, between the North Sea and the Baltic, across the Malay Peninsula and on many interior lines between bodies of water, and in every case the ship railway will be found to be in the cost of construction at least 50 per cent less than that of any adequate canal of the same capacity, and the cost of its maintenance will always be less and that of its operation no greater.

The author is glad to state that since his paper was written for the Canadian Society of Civil Engineers, the Department of Public Works of Canada has decided to widen and deepen the lock at the Sault Ste Marie now under construction by the Canadian Government, and he is confident that that Government realizing and fully appreciating the immense advantage which a greatly enlarged waterway down the St. Lawrence river would give to commerce, will not hesitate to change its plans there also and increase the dimensions of the canals and locks to meet the requirements which the author laid down in his paper—nothing less than 20 feet

and 5,000 tons and as much greater as possible. Nor does he have any doubt that when this subject and the facts that have been presented by the author and by other engineers are carefully considered by the Dominion Government, it will unhesitatingly approve the proposition to guarantee the interest for a term of years on the cost of construction of the Huron-tario Ship Railway as it has done on that of the Chignecto Ship Railway, and it behooves the United States government, if it would promote the commerce of Lake Erie and the Detroit river seeking the eastern sea-board, to give a contract on the same terms to a company of its citizens. We will then have two converging lines of an immense commerce pouring their freights into Lake Ontario through adequate channels. Uniting they will pass down the enlarged waterway of the St. Lawrence river to Montreal and Liverpool, Havre and Hamburg.

RECENT PROGRESS IN CIVIL AND MECHANICAL ENGINEERING AND ASTRONOMY.

BY COMMITTEES OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read March 10, 1891.]

Report of Committee on Civil Engineering. (Mathematics of Civil Engineering.)

BY C. L. SAUNDERS, CHAIRMAN.

I shall endeavor to-night to bring to your attention in a concise form, the recent progress in the mathematics of Civil Engineering, and a few of the more notable changes of the year in this branch of mathematics. By this I mean that development of mathematics as applied to Civil Engineering, which is gradually, but surely, replacing many of the old empirical formulæ and substituting new equations and mathematical deductions which are the result of many years' experience and extensive as well as thorough and often very expensive experiments and trials. Moreover, the mathematical progress of Engineering is largely due to the enlarged and rapidly extending field of labor, and the prominent position that Engineering, as a profession, is taking to-day in the remarkable and wonderful advancement of the country in the use, development and expansion of the natural resources, manufactured and cultivated products.

When we pause to consider the remarkably few years in which the Engineering Literature that we are using and by which we are governed to-day, and which the world possesses, has been accumulating, and the extremely short period in which all that Literature which is now the authority for Engineers has been written, compiled, analyzed, and culled, till at this time the Literature of the Engineering Profession stands upon a firm and enduring foundation, and is nearly as voluminous and exhaustive as that of the Literature of History or Belles-Lettres.

This unparalleled growth and advancement of a Profession, the sudden rise, development and prominent position accorded to its written Litera-

ture in both the literary and economic portion of the country's growth we can safely assert has taken place within the lifetime of a comparatively young man of to-day.

When I first commenced this paper it seemed to be desirable to make an open comparison between the mathematical formulæ and their deductions as in use to-day with those in use a few years ago, but it soon became evident that in order to do this and make it a fair comparison, the paper would not be one which it would be desirable to read at any one meeting, so it has seemed best to confine myself strictly to the mathematical progress in Civil Engineering for the last year, noticing hurriedly and shortly many of the little mathematical solutions developed by different Engineers for the solving of some problem that their work has called to their attention, and they have thought of sufficient merit to publish from time to time, in different Engineering papers and technical publications.

That thorough and exhaustive mathematical development, analysis and treatise of the same which is to be found in the published books of the day will be considered without the province of this paper as it would render the same too long and uninteresting, it being more advantageously considered in the class-room or office.

One of the most striking advancements in mathematical and engineering science is seen in the enlarged and increasing field and acknowledged accuracy accorded to graphical statics. To-day all Engineers eagerly and confidently employ graphical statics in the place of the long, tiresome and often inaccurate method of computing strains and stresses by algebraic equations, trigonometry or the "method of moments."

Graphical statics may safely be used at a great saving of labor, worry and time for the solution of most of the problems confronting the Engineer in the construction of roofs, bridges, floors, arches, piers, trusses, towers, dams and many of the complicated problems met with by the Mechanical Engineer in the designing and proportioning of machines and engines. Graphical statics as in use to-day does not require the Engineer to study the question way back to the beginnning for the derivation of the strain diagram, but may be applied direct to the problem with only the knowledge of the fundamental principles, referring to one of the many text books for a solution of the special case.

Within the last year many short, concise, as well as unique, solutions of Engineering problems by graphical statics have been published from time to time in various technical publications, and we are glad to learn that "*Mechanics*," intends to give in its columns a translation of "The Treatise on Statics," by Maurice Levy, a very thorough and exhaustive work on the practical application of graphical statics to the theory of stresses and strains in Engineering structures and the proportions of masonry, published in 1888. This translation will remain for many years the basis of the science of graphical statics. The subject is treated in this work at great length of detail and with a precision which is marvelous when we consider the numerous practical examples worked out to illustrate the methods proposed; and it is on account of its application to practical construction and adaptability to the different problems of

Engineering, that the work is of indispensable value to all Engineers.

It will be safe to say that within a few years the importance of a thorough knowledge of the fundamental principles of graphical statics will be so recognized that it will be taught in the high schools of the country; for it offers to the practical man methods of computation that are short, convenient, as well as exact, because they afford the eye a picture of the measurements sought in which an error is readily seen.

Most of the recent text books on Civil Engineering, mathematics and computation have contained many problems which are explained and solved by graphical statics.

The almost universal use of diagrams for the solution and explanation of problems involving empirical or deduced formulæ strikes the student of Engineering as an advancement of no little moment.

Now the Engineer is able to solve directly, quickly, and with no liability of error most of the important problems involving equations by referring to a diagram of the co-ordinates of the curve of that equation.

Where a few years ago a diagram or curve of an equation was to be seen only in technical journals, and not very often then, as it appears to have been but little used as well as its application having been greatly misunderstood, to-day diagrams of equations, formulæ or results of experiments are to be met with on every hand, the knowledge of its utility not being limited to the scientific man alone, for the large circulation of our scientific papers and the prominent position that Engineering as a science holds in the economic and commercial world has not only educated but compelled the business man to read, understand and use diagrams in his office and for his business.

There is hardly a technical paper published which does not contain diagrams explaining some Engineering mathematics, and with their use the reader comprehends the problem without any trouble or tedious study of equations. Within the last year many diagrams of wages, cost, excavations, masonry, moments of inertia, bending moments, wind pressure, bridge weights and flow of water in pipes, canals, and over weirs, have been published till there is placed within our reach easily accessible diagrams, which, with little alteration are readily adapted to most of the ordinary problems confronting the Civil Engineer. Without the aid of these diagrams the Engineer's only resource is the long, tedious and often inaccurate method of figuring the problem from the equation or formula itself, whereby the liability to error from carelessness is large, while if the diagram is used any mistake is readily shown.

Owing to the remarkable and rapid growth of the Southwestern States and the occupation of their lands by settlers for agricultural purposes, there has been a great amount of attention called to the problem of land irrigation by means of irrigating canals, resulting in the formation of wealthy irrigating land companies. The wonderful development of that portion of the country in this manner has necessarily drawn attention to the flow of water in pipes, canals and over weirs.

The many valuable results obtained from experiments made by the Engineers interested have been augmented by extensive, able and expensive

experiments made by those connected with the use of water for power and for mining purposes. The great importance of this question is now fully realized by the farmer and miner as well as by the Engineer and manufacturer interested in water-works and sewers for cities and towns.

Much of the technical literature of the preceding year is devoted to experiments and diagrams on the flow of water with discussion of the same. By the aid of these diagrams and experiments the explanation of almost any question liable to occur in connection with this subject may be obtained with sufficient accuracy for the ordinary purpose of the Engineer from some one of the numerous published papers on this subject, among which I will only mention a paper on "The Relation Between Rainfall and Discharge of Sewers in Populous Cities," by Emil Kuichling, *Trans. Am. Soc. C. E.*, January, 1889; "The Results of Investigation relative to formulæ for flow of water in Pipes," by Edwin R. Weston, with discussions and diagrams, *Trans. Am. Soc. C.E.*, January 1890; "Irrigating in India," by H. M. Wilson, *Trans. Am. Soc. C. E.*, November, 1890; "Recent experiments on the flow of water over weirs," by M. Bazin, *Proceedings Engineers' Club of Philadelphia*, January, 1890: and many others which are equally important and deserve mention.

Before leaving this subject it would seem desirable to suggest that the many different results and papers should be collected and published in one volume.

Closely connected with the flow of water in pipes is the problem of earthen and masonry dams, to which considerable space has been devoted in the technical literature of the year. It would be impossible to discuss the question of "The stability of earthen and masonry dams," or the relative merits of "curved or straight dams," within the limits of this paper, so I will only mention and refer you to the paper on "The stability of earthen and masonry dams," by George Farren, *Proceedings of Liverpool Engineering Society*, January, 1890, and call your attention to the dams built in connection with the New York water supply, as the "New Croton Dam," "Quaker Bridge Dam" and "Sodom Dam," which have been figured, analyzed and discussed in so many of our technical journals that the mathematics and strain diagrams of almost any desirable form of dam are now readily obtained.

It would hardly be just to leave this branch of Engineering without mentioning the rapid progress that has been made in the building of tunnels, both for water supply and railroad purposes. Among those under construction within the last year we should mention the following tunnels: The Hudson River, St. Clair River, the Chicago water-works, the Milwaukee water-works, the Cleveland water-works, the East River, the Niagara River Power Company, and many others.

The new methods adopted in surveying and aligning these works make an important addition to Civil Engineering. It would be an interesting paper to compare the different methods used in their construction. We can only regret that there is published so little of the detail of the laying out, alignment and mathematical computation met with in their construction. The great fault of this class of publications appears to me to

be that there is not enough attention paid to the publication of the mathematical details and cost of construction, most of the articles being devoted to the construction work.

The discussion of wind pressure has occupied an important place within the last year, and considerable information has been obtained on this subject by various experimenters. Within the last few years there has been a radical change in the consideration of wind pressures, and the vital importance of an accurate knowledge of the measurement of wind velocities is now recognized. Diagrams of wind velocities and pressure have been published in *Mechanics*, January, 1891, *American Architect*, July, 1890, *Engineering News*, pages 259, &c.

The important recognition that is now accorded to the subject of transition curves and the mathematical developments of the same by different Engineers, as well as the enthusiasm with which different writers uphold their favorite method should be brought to your notice as of importance in the mathematical development of Civil Engineering. The Engineer of to-day must keep himself thoroughly posted on this subject, for it is to be found in few places outside of the published articles of different Engineers on their own individual practice in special cases coming within their work, and it is to be hoped that some one will devote an article to this important branch and give us in a collective form the different methods now adopted.

It would be hard to-day to find a young engineer who is not thoroughly conversant with the art of photography, the development of the negative, printing and toning. Many engineers you will find to be enthusiastic amateur photographers and possess a camera or a kodak; and in their work as surveyors or engineers it becomes a great aid, for, of the truth and reliability of the camera as a recorder of topography there can be no doubt. The importance of using a camera in surveying is no longer questioned and considerable attention has been paid to the development of photographic surveying. While it would not be safe to predict any great development in accuracy and precision in surveying or in the use of the camera as a means of obtaining measurements and details, progress is the order of the day and the use of the camera by topographical engineers, at a great saving of note-book, time and labor, combining as it does considerable pleasure, will undoubtedly cause the camera to become the friend and companion as well as the most reliable of note-books with many engineers.

The popularity of stadia surveying with the engineer has increased within the last year, and as the mathematical accuracy of this method becomes more developed and better understood and its great utility and reliability are realized, many engineers will turn their attention to the enlargement of its field and apply its methods to their own advantage in daily practice. A number of diagrams of stadia surveying have been issued during the year, but there remains much more to be expanded, enlarged and corrected in order to obtain the precision and accuracy desirable and possible with the use of the stadia wires in surveying. Many engineers still doubt the reliability, accuracy, as well as the practicability,

of using the stadia. Here it would be well to pause and consider if there is not a veil of credulity in the minds of many good surveyors in regard to what they think is a rather vague method of surveying. As yet I know of no publication containing a complete table for stadia work deduced from the corrected formulæ, while those published are not carried far enough nor complete enough to meet the demands of all engineers.

There has been considerable advancement in the improvement and use of calculating machines; Manheim's and Gunter's Slide and Engineer's Rule, are both rapidly growing in favor. They save the user much time and vexation. The utility and accuracy of the planimeter is rapidly becoming better understood, while the importance to an engineer of fully understanding the principles of their construction and operation has greatly increased within the last year. A number of articles have been published explanatory of the method and advantages of both slide rules, planimeters and other calculating machines.

We should not finish this paper without a short and rather cursory consideration of the year's progress in the calculations of strains and stresses of frame structures. There has been added much valuable information and knowledge to the old methods of calculation, as well as many entirely new creations or extensions of the methods formerly in use for the calculating of strains and stresses. There is no branch of engineering which has so largely occupied the attention of the engineer or has been accorded the space in our technical literature or brought to the general consideration of the engineer, as there has been granted to this important subject. It will be impossible to mention any of the methods of computation used in the erection of the great bridges, arches, piers or buildings within the last year in the short time allowed to a paper before this Club. There is no branch of engineering which has been reduced in so short a time from comparative guess-work to a mathematical certainty, in which the possible error is reduced to a minimum as there exists now in the methods of computation of the strains in bridges, arches and roofs. When we consider the knowledge that is placed before us of the material of which the bridge or roof is to be constructed and then pause and consider the few years in which all our technical literature has been written and developed, as well as the short time occupied in the growth and perfection of the processes in use to-day for the manufacturing of the material, together with the rigid tests and inspection to which it is subjected, the builder expecting the product of the steel and iron manufacturer to fulfill conditions and stand tests which but a few years ago would have heaped ridicule upon the unfortunate who even suggested the probability of the present specifications and conditions which are required of iron and steel, and we can safely assert that in the wonderful development and perfection that is occurring in the manufacture of engineering material, the mathematics connected with their manufacture and use have kept shoulder to shoulder with the engineering construction, and to-day we find that the engineer works out his problem with a feeling of security and success, knowing he can safely rely upon obtaining material which will fulfill the demands and specifications.

Consider but a moment the vast amount of labor, advancement, prog-

ress, together with the step in civilization occasioned by the wonderful new processes which have been invented, created, made, employed, improved, and developed in order that the world may have such wonderful creations and works of man as the Red Rock Cantilever bridge, the Forth bridge, the New Orleans bridge, the Eiffel tower, the Croton aqueduct and many other works impossible to mention here, that but a few years ago would have been considered but the dreams of an enthusiast. Who shall then say where the engineer will stop, for as soon as he dreams of some great feat of engineering then he figures that given material which will fulfill certain conditions, he can accomplish a great step in the civilization of the world and bring nations a day nearer together and thus into closer unity. No sooner has he awakened from his dream than he finds some mechanical engineer offering him the material he desires which will fulfill all the conditions and more. It is no false assertion and one which will not suffer contradiction when we assert that the profession of engineering is to-day doing more to revolutionize the economic methods and history of the world than any and all other professions. But look a moment at what engineering has developed for the people as a field of labor, what it has given to the world in deversified industries and products, and placed within the reach of any man as possibilities for the development of his own talents and abilities, then we will believe the great influence exerted by the engineers on the progress of the country.

Report of Committee on Mechanical Engineering.

By WALTER MILLER, CHAIRMAN.

The growth of the ship-building industry on the Great Lakes in the last few years has been something phenomenal. Our representative in Congress, Mr. Burton, stated in the speech before the House that according to the official reports the city of Cleveland built at its ship yards in 1889 more tonnage of iron and steel vessels than any other city in the Union. The aggregate of the net tonnage built here during the year was 22,182. The tonnage of vessels built at the Philadelphia yards, which ranks next, was 19,299 tons. The tonnage of the Wilmington yards, which is third on the list, was 4,913 tons. In this connection, increase in the construction of steel vessels is much more rapid at Cleveland than at any of the other lake ports. He farther says that the carrying capacity of the boats has increased more rapid than the vessel tonnage. This is due to a number of causes, chief among which is the great increase in the speed of vessels, due in a measure to the general introduction of triple expansion engines of high power, and also to improvements in the machinery for loading and unloading. The harbors located upon the Great Lakes have the best machinery and most perfect facilities for the loading and unloading, which are to be found anywhere in the world. The labor of loading and unloading ships, which until recently required days, is now performed by the assistance of hoisting machinery in a few hours. Will say further in passing, that the increased out-put from the Cleveland yards for the year 1890 is about in the same relative proportion as mentioned above.

The interesting part in marine engineering in the past year, is the introduction of twin screws While the subject is not a new one, neither here or abroad, in fact it is a matter of record that the twin screw system was of the earliest method of propulsion on these waters, and has been followed for a number of years with indifferent success, and finally abandoned. Of late years it has been brought forward in fast cruisers and war ships, and the reason for its adoption in these vessels was to obtain a large power in a limited space. In these ships the propelling machinery is located below the protective deck, and as this deck extends below the water line at ship's side, thus the height under deck being limited to the draught of water therefore the stroke of the engines are of a necessity very short, and as the power of an engine is the product of pressure and space passed through in a given time by the piston, consequently owing to the limited height of deck, the limits of piston speed have been about reached. It was for the late Mr. John, of the Barrow Ship Building Co., England, to bring this system of propulsion prominently before the merchant marine. As he foresaw a limit to the power in merchant ships, whenever an opportunity offered, he strongly advocated the adoption of the twin screws and middle line bulkheads in the fast passenger service between New York and Liverpool, and the correctness of his views is seen in those magnificent specimens of marine architecture brought out in the past few years. This system of propulsion has been made practicable by the modern steel ship construction, less length of outboard shafting strongly supported, reducing the liability of bent shafts and broken bearings.

It has fallen to the lot of the Cleveland ship-builders to bring out the first twin screw of modern design for Lake service. This ship will be completed June next, and is of the following dimensions: 260 ft. keel, 278 ft. over all, 38 ft. beam, by 25 ft. moulded depth, and 12 ft. draft of water, co-efficient of displacement .61, contract speed 16 miles per hour. She is to have full length cabin of mahogany, finished in the natural wood, and is to have sleeping accommodation for 262 passengers, and dining-room seating capacity for 100. Her machinery consists of two sets of inverted vertical triple expansion engines, cylinders 20x32 in., 52x36 in. stroke; two sets of duplex independent air pumps and condensers; two duplex boiler feeders; one duplex cold water pump to supply the clean water service; one duplex pump for closets, and one duplex pump for fire and general use on ship board; one duplex water ballast pump. This water ballast system extends the entire length of the ship for as far as practicable, and has a capacity of about 450 tons. The boilers are two in number, double ended, 13 ft. diameter by 21 ft. long, with six furnaces in each, built of steel 1 in. thick, and are to stand a working pressure of 160 lbs. steam. The boilers are located forward of the engines, and lengthwise of the ship, with an air-tight stoke hold at each end. There are two large steam fans located one in each fire-hold, the one in the after hold draws the heated air out of the engine room and delivers it to the stoke hold, the fresh air is supplied to the engine room by two 30 in. down-cast pipes. The fan located in the forward stoke ho'd draws the air out of the galley

officers' mess and dining-room, as well as taking air from two 30 in down-cast pipes, and delivers to the forward stoke hold. The electric light plant consists of two 350 light dynamos, each driven by separate engine. The ship is supplied in addition to the above, with steam capstan windlass forward for anchors and chains, steam steering located on the main deck under pilot house, and steam capstan aft. The main engines turn propeller wheels 11 ft. diameter by 16 ft. pitch, and turning at 130 revolutions per minute, it is expected will propel the vessel at a speed of 18 miles per hour.

As the machinery for Lake vessels has become so heavy; especially the boilers that some safer and more rapid method of placing the machinery on board had to be considered. This work as commonly done in the case of the boilers was to use jack screws and by blocking until the boiler was of sufficient height to be run in on board, then lowered down in place in the same manner, and in other cases two heavy square oak timbers of sufficient length are set up on end on the dock and far enough apart to let the boiler swing clear. These timbers are capped with an oak piece bolted and kneed. The hoisting tackle consisted of two four-sheave blocks, large enough to receive 9 in. lines and with snatch blocks to lead the lines to a couple of gins operated by horses and men to attend the slack. When the boiler was raised high enough to swing over the rail the guys staying the heads of the shears would be slacked off until the boiler could be lowered into the hold of the vessel. Thus it will be seen this manner of dealing with these heavy weights was expensive and very unsafe. At one of the Cleveland yards there is in process of construction a pair of steel legs of eighty tons lifting capacity. The entire plant including the hoisting machinery is about finished and the erection (a no small matter) will be commenced at an early day. There are three steel legs of box section, the two front legs are 100 ft. 5 in. long from center to center of pins and the back leg is 130 ft. 6 in. from center of screw to center of pins. The lower end of the back leg traverses in a guide and is moved in and out with a screw a distance of 40 ft. thus giving a horizontal movement of the block 49 ft., the two front legs are built up of steel plate and angles and are 36x44 in. in the middle by 20 in. square at ends. The back leg is built up of the same material similar to the front legs and is 42x50 in. at the middle and 20 in. square at ends. The two front legs are capped at the top and bottom with cast iron caps and are bored through at the proper angle to receive the pins, which are 9 in. at the top and 7 in. diameter at the bottom. The bottom ends are stepped into a casting 6x8 ft. placed 26 ft apart and rest on piles on the edge of the dock. These castings with journal caps are to receive the 7 in. pins at lower end of front legs. As mentioned above the shear legs are built up of plate and angles; the plate used throughout is of ½ in. steel and of as long lengths as possible and get a good shift of butts. All the butts are double strapped and triple rivetted. The corners are connected with 4x4 in. angles double rivetted. At the ends of all of the legs the plating is doubled for a length of 12 ft. besides being stiffened the entire length with 3½x6 in. angles and tied across with plates

10 in. wide at intervals of 10 ft. The top and bottom ends of back leg have wrought iron straps bolted on the inside and are bored 11 in. and 7 in. respectively, the 7 in. to engage the crosshead, which is fitted with brass nut for screw and the 11 in. ends to engage the pin connecting the top end of front legs. The straps for the upper sheave block are bored 11 in. and the block hangs suspended from the cross pin. This block has five sheaves and the lower one four, thus making, with an extra sheave in top block eight running parts of a 1⅝ in. diameter nineteen strand steel cable capable of sustaining the safe load of 11 tons. It is intended to use the extra sheave in the upper block for a single whip; a pair of smaller blocks will be shackled at the outer end of top pin, to be used for masting vessels and other light work. The sheaves in the large blocks are of cast iron 48 in. diameter turned and grooved and are bored and bushed with brass to fit 8 in. pin. The sheaves are separated by ½ in. steel plates and cast iron distance pieces. The lower end of back leg as described above runs in a guide of box section in which is placed the screw. The nut is a square forging which forms the crosshead as well, and is bored to receive the threaded part of the nut which is of brass and in four parts. This part of the nut can be renewed at any time. The crosshead is formed out of this square block by having trunnions forged on and are turned to fit the straps at end of back leg. The guide blocks are put on the trunnion outside of these straps. The screw is made of best forged scrap iron 7 in. diameter and 48 ft. long and is threaded 43 ft. nine threads per foot. The thrust is taken by a series of collars at end of screw working in a corresponding series of collars in the bearing. The hoisting plant is quite complicated and cannot be fully descr ed without the drawings. The following are a few descriptive points: The main hoisting drum is 48 in. diameter and grooved to receive the 1⅝ in. diameter wire freely. There is another drum 30. in diameter for the single whip and one winch head for any other light work. The motive power for this hoisting plant consists of a vertical compound engine 8 and 14 in. diameter of cylinders by 12 in. stroke and is supplied with an independent air pump and condenser. When working the large hoist the engines are expected to make 250 revolutions per minute and with two changes of speed in the gearing will give a speed to hoist 1 ft. 6 in. at the slowest and 3 ft. at the fastest speed per minute, and with the same changes of speed the back leg moved horizontally by the screw, will be 3 ft. and 6 ft. respectfully.

The subject of rapid transit mentioned in progress of mechanical engineering for the year 1890 will be reviewed to see what progress has been made, during the past year. The electric system for street car propulsion as used in this City has got a strong foot-hold and seems to have come to stay. Its opponents had figured out that at the first severe snow storm the entire system would collapse. There has been but one snow storm so far this winter that has been anything like the old time blizzard, but this system has held its own, as well as any of the others, in fact one part of a prominent horse car line had to be abandoned. While the electric system has its many objectionable features improvements are being constantly made that will soon class it as one of the standard systems of rapid tran-

sit. As far as speed is concerned it is all right, as this point has never been questioned. The electric plant, as will be conceded by all is not perfect, but any system that could not beat a pair of smooth shod mules on a slippery frosty morning is a very poor one indeed. The cable plant laid down in this City has been completed and is in full operation. It is safe to say that no other cable line in this country has been started and put in full running order with as little delay and stoppage as this one. The work seems to have been so well planned and thoroughly built that it moved right along from the start. In fact, the entire plant has been pronounced by expert engineers to be the best yet built.

The manufacturing plant, building by the Walker Mf'g Co., of this City, while it is not completed, promises when finished, to be second to none. No figures are at hand to give an idea of its magnitude, but trust that in the near future the Club will be favored with an interesting paper giving a description of the entire plant and work-shop system.

Compounding locomotives in this country the past year has attracted considerable attention and from all reports published, the changes have resulted in a positive gain. In a review just published on the above subject by the *Railroad Engineering Journal* of a compound locomotive on the Brooklyn elevated road, it was stated that the economy in water consumption was 23.8% less water in doing the same work than with the simple engine. Furthermore, the boiler of the compound engine evaporated 23.3% more water per pound of coal than the simple engine. The same old mystery still exists with the opponents of the compounding locomotive as did exist years ago with the marine engine and still exists with the opponents of the triple and quadruple engines. They cannot reconcile their figures to the actual results in practice. The review stated that the steam pressure carried was 155 lbs. in the compound and 140 lbs. in the simple engine and that no doubt the economy in the water consumed was due in a measure to this fact, but what to attribute the superior evaporative efficiency of the compound boiler, they are at a loss to say. In looking at it one way, it seemed to be due to the fact that there was less demand for steam in a compound engine as the boiler was larger in proportion to the cylinder capacity in the one case than in the other, and assuming this to be true the remedy in the simple engine was to make the boiler larger, then again it was agreed that part was due to the softening of the exhaust and as it was at greater intervals it did not lift the coal from the grate bars. Then it was suggested, if the extra expense incurred in compounding was utilized in a larger boiler and less blast from the exhaust and one half as often the economy would equal that of the compound. Then the vexed question came up how to get the two exhausts into one. The reviewer says that he does not agree with his contemporaries when he says just where the economy is obtained is a secondary matter. How it came about is what we want to know and until we do know will not accept these conclusions but it is a matter of fact that the idea of compounding locomotives is steadily gaining ground every day and very soon will be adopted by all of the leading railroads as it was in the marine service.

Report of Committee on Applied Science.

By Chas. S. Howe, Chairman.

In preparing this report I have confined myself entirely to one department of Applied Science, namely Astronomy. No wonderful discoveries have been made in this science during the past year, but good steady work has been done along many lines. Much of this is too technical to be interesting except to those who are personally engaged in astronomical work. I shall speak only of those subjects which may be of interest to members of this Club.

Some results of an investigation of the motions of the Moon which are of interest to us have been published during the last few months. The author is Dr. Stockwell, one of our own members. This work is intensely mathematical and of a character only undertaken by a few specialists in mathematical astronomy. I shall merely make a brief statement of the general character of the work. From the theory of gravitation and the observation of the Moon, tables are prepared by means of which the place of the Moon can be computed for any past or future time. But these tables are not correct. Either the theory of gravitation is at fault or the observed data which have been used are not perfect. The latter is undoubtedly the correct explanation. The error during any short period is very small, but when we compute the dates of some remote eclipses they do not agree with the historical statements. By means of some of the best authenticated of these eclipses the tables of the Moon have been corrected, but even then the computed dates of others do not agree with the historical statement. Dr. Stockwell finds in his investigations that certain terms have hitherto been computed wrongly and that other terms which were supposed to be so small as to have no effect, do have an effect. Taking these into account he has computed sixteen of the ancient eclipses and finds a remarkable agreement between his results and the historical statement. If these results are verified by further investigation they will form an important addition to our knowledge of the Moon's motions.

In regard to the planets some interesting results have been published during the past year. First, with regard to Mercury. In the year 1800 Schroeter, an astronomer of Germany, found that the southern horn of the crescent of the planet was blunted. He explained this by supposing it to be due to a mountain over eleven miles high which cut off the sun's light. By careful watching he concluded that Mercury rotated on its axis in 24 h 4 m. This was the result of 20 years of observation. Before this no one had observed any markings upon the planet. Telescopes were very small and Mercury is visible for a few days only at periods two months apart and then for a short time after sunset or before sunrise. Some faint markings were also seen upon the surface. The blunting of the southern horn has since been seen by several observers, but so faintly and at such irregular periods that astronomers have hesitated to accept Schroeter's conclusions. But a little more than a year ago Schiaparelli of Milan published the results of observations made during 1882-3 and also 1886-7. From

these he concludes that Mercury rotates upon its axis once during each revolution around the sun or in 88 days. Instead of confining his observations to the short period after sunset as Schroeter had done he made his observations during the day time. Having a larger telescope he could do this. Some idea of the difficulty of these observations may be had when we remember that at this time Mercury was only 4 or 5 seconds in diameter or was as large as a ball one inch in diameter seen at a distance of 8 to 10 miles. Schroeter observing the planet from night to night of course saw the same markings and hence concluded that it rotated in about 24 hours. But Schiaparelli, observing the planet in the daytime could see that these markings were visible for long periods and so obtained his final result. As the planet rotates once during each revolution around the sun it must always turn the same face toward the sun. The axis is found to be inclined 90° to the plane of its orbit and thus the sun is always over the equator. If the planet moved regularly in its orbit the sun would remain fixed in the heavens; but owing to the eccentricity of its orbit and the consequent irregular motion, the sun has a slight swaying motion with a period of 88 days. What a curious state of affairs must exist here. On the side toward the sun it is always day and must be intensely hot. On the other side it is eternal night and must be perpetual winter There are no days or nights as we know them, no hours, months, years. There are no seasons except as the varying distance from the sun produces them.

Much the same thing has been determined in regard to Venus. From observations made in 1666-67 Domeniel Cassini concluded that Venus rotated in 23 h. In 1726 Bianchini found a period of 24 days 8 hours. J. J. Cassini in 1740 taking the data of the two preceding found that they were all satisfied by a period of 23 h 20 m. Schroeter watched the planet for nine years before he found any spots sufficiently marked to enable him to determine the rotation period. After a number of years of observation he placed the period at 23 h 21 m. De Vico after 10,000 observations only changed this latter result 22 seconds. Thus matters rested until Schiaparelli began his work of observing and reducing these old observations. He has finally concluded that Venus like Mercury and the Moon rotates once during a revolution around the sun or in a period of 224.7 days.

Considerable work has been done upon Mars during the last year, especially by French and Italian astronomers, but nothing very striking has been discovered. All astronomers are looking forward with a great deal of interest to 1892 when Mars will be at its most favorable opposition and the duplicity of the canals will be definitely settled.

I might mention some observations of the variable star Algol as showing what has been done in one department of astronomy. Algol is a star in the constellation Perseus. It is ordinarily of the 2nd magnitude; from that it descends to the 4th magnitude in 3½ h, remaining there 20 minutes, then it begins to grow brighter and in 3½ h. it becomes of the 2nd magnitude again, at which it remains for 2 days 13 h. Now for some time it has been thought that this change in light was due

to a dark, invisible planet or companion which revolved around it in between two and three days. Prof. Vogel and Dr. Scheinerhame recently determined the following dimensions of the two stars:

Diameter of Algol	230,000 miles.
Diameter of invisible satellite	180,000 "
Distance between their centers	700,000 "
Velocity of satellite in orbit	12 miles per sec.
Motion of both toward our sun	5 " " "

These results are obtained upon a star which has no perceptible parallax—that is, it is at least 2,000,000 times as far from us as our sun is from the earth.

Thirteen new minor planets were discovered during the year 1890, bringing the number up to 301. In the two months of this year four more have been added to the list.

Seven comets were discovered, all of them too small to be seen with the naked eye.

Much more might be said upon this subject were it not for the reason assigned at the beginning of this report.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF ST. LOUIS.

347TH MEETING. MAY 6, 1891. The club met at 8:15 p. m. in the club rooms, President Burnet in the chair and thirty-three members and three visitors present. The minutes of the 346th meeting were read and approved. The executive committee reported the doings of its 111th meeting.

On motion the name of B. E. Chollar was referred back to the executive committee for further information.

Mr. G. T. Thompson was elected a member. The name of Mr. E. A. Herman was proposed for membership.

Prof. F. E. Nipher presented the paper of the evening on "The Output of an Electric Motor; Including a Discussion of Journal Friction."

Mr. Nipher discussed the output of a series motor. It was shown that the maximum output delivered on the pulley of any series motor having its terminals maintained at any fixed potential difference E, as also the maximum commercial efficiency could be expressed in terms of that potential, and two constants which characterize the machine. These constants are its resistance and the current required to run the motor when the load is wholly removed from its pulley. This current for any machine depends solely on the resisting moment of journal friction, which is sensibly constant at all speeds. When the motor drives its load by means of a belt the power consumed in the journal is independent of the load, and depends mainly upon the speed.

Let i_0 represent the current which will flow through the motor when it is running without load, and i^1 the current when the motor is loaded so that it cannot run. Then the current for maximum output is

$$i_1 = \tfrac{1}{2} (i^1 + i_0)$$

The current for maximum commercial efficiency is

$$i_2 = \sqrt{i_0 \, i^1}$$

or the current for maximum efficiency is a mean proportional between the currents before mentioned. When the resistance of the machine is known, it is evident that i^1 can be computed for any value of E. By Ohm's equation

$$i^1 = \frac{E}{R}$$

The maximum numerical value for the commercial efficiency of the motor was shown to be

$$y = \left(1 - \sqrt{\frac{i_0}{i^1}}\right)^2$$

For example, a motor having a resistance of 4 ohms is found to require a current of 1.5 amperes to run at its normal speed when it has no load. When the supply potential is 150 volts a current of i^1 of 37.5 amperes would flow through the motor if at rest. Hence the current for maximum output is $\tfrac{1}{2}(1.5+37.5)=19.5$ amperes. The current for maximum efficiency is

$$\sqrt{1.5 \times 37.5} = 7.5$$

amperes. The maximum efficiency is 0.64.

The $E\,M\,F$ of the motor at maximum output would be 150—19.5×4=72 volts, and at maximum efficiency it would be 150—7.5×4=120 volts.

The general expression for commercial efficiency is

$$\nu = 1 - \frac{i - i_0}{i^2} \quad \frac{i_0}{i}$$

So that the efficiency at maximum output, when i=19.5 is 0.44.

The useful power in watts delivered on the pulley of the dynamo is $w=(i-i_0)(E-i\,R)$. The maximum output is therefore 1,295 watts, or 1.74 horse power, while the output at maximum efficiency is 720 watts, or 0.95 horse power.

The corresponding equations, which apply in shunt and compound motors are somewhat more complex, and will be presented at a future meeting.

Discussions followed by Messrs. Farnham, Seddon, Nipher and Holman.

For the next meeting, May 20, a paper on "Our Viaducts Across the Railroad Tracks," by Mr. Carl Gayler, was announced.

Adjourned.

ARTHUR THACHER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

281st Meeting, May 6, 1891. The 281st meeting of the Society was held at its rooms, Wednesday evening, May 6, 1891, at 8 p. m. President L. E. Cooley in the chair and over 40 members and visitors present.

In relation to the minutes of the previous meeting, Mr. Isham Randolph wished to correct a misstatement he had been led into in his eulogy on Mr. Miller. He had since learned that Mr. Miller did not build the Missouri river bridge.

The following members were elected: Messrs. J. C. Slocum, W. C. D. Gillespie, Wm. H. Hendren, Theodore W. Parvin, Morgan Walcott, B. Thomas.

Mr. Geo. W. Dorr was proposed for membership.

The secretary gave some information on the approaching meeting of the General Committee of Engineering Societies convened to organize for the preliminary work of the International Engineering Congress and Engineering Headquarters for 1893.

President Cooley spoke on the subject of an annual convention of the Society. He said: It used to be the custom of the Society to hold something in the nature of an nual convention, in which especially our members who were not residents of the city would be interested and usually attended. That custom has gone by default for four or five years. The question was raised in the directors' meeting as to the advisability of holding such a meeting this year, and if it is to be it should be put on foot at an early date. The general conclusion that we reached in the matter was that it might be inopportune to hold one in June, for our former experience was that t came pretty close to the first of July, the weather was warm, other societies of the country were holding annual conventions, and the suggestion was made that it would be well perhaps, after a summer vaca ion to call our first meeting with that object, to spend a day or two with it and devote ourselves to this city and get all our members from abroad together as nearly as possible with a view of showing what Chicago is doing, and learning something of what is going on ourselves. I know there are many things which have been done in the last four or five years with which I am not familiar, and there may be others who feel the same. That was the result of the deliberation that we had on the subject, and if any one cares to make an expression of opinion in regard to the matter we shall be glad to hear them briefly at this time I bring it up more especially with the idea of having the matter before you for consideration at the next meeting. Has any one any thoughts that they would like to express on that question, the President did not design to state all sides of the case so much as to close the debate.

If there is no other matter to bring up before the society in the way of miscellaneous business, we will proceed to the special order of the evening, which is the con

sideration of the resolution in regard to the change of name of the Society. I would say in regard to that matter before we enter upon the debate,—I will ask the Secretary to read the constitution relating to the amendments, for the information of the society, so we can all be informed as to any procedure that it may be necessary to follow.

The Secretary then read Article 6 of the Constitution and the President announced the question open for discussion.

MR. RICHARD P. MORGAN:—My recollection is that at the meeting when this subject was last considered the negative of the question was really discussing their side of the question. I only have a word or two after that, and I will add them after the negative of the discussion conclude their remarks. I will only add to what has already been said, upon this subject, a fact that I believe has not been recognized—the census of 1890 shows that the center of population in the United States is about half a day's journey nearly due south of Chicago, 20 miles northwest of Columbus, Indiana. I mention that as a fact in support of changing the name from Western Society to the Chicago Society of Civil Engineers. A great deal could be said in detail in support of this question, but it seems to me that to say much more than has already been said would be a reflection upon the intelligence of the members of this Society, and I shall be willing to let the matter stand on the discussion that has already been made.

MR. ISHAM RANDOLPH:—Mr. President, I have already spoken upon this subject and given my views quite fully. I have very little to add except on one question that has arisen in my mind since the last meeting. As to the propriety of changing the name my mind is fully made up, as to what it should be changed to I am not so well satisfied. It has been suggested to me by one or two, and the suggestion seems to me to be good, that of changing it to the Institute of Engineers of Chicago, and it seems to me to be a choice between new names, and not a choice between an old one and a new. I think the old one should be changed to the Institute of Engineers, Chicago, the idea being that it should be an institute of engineers, and there should be divisions in the institute—division of mining, division of electrical engineers, and so on.

SECRETARY:—Mr. President, as Secretary I should say that the question has been brought to my attention by several of the members who did not call themselves civil engineers, some of our mechanical and mining engineers—we have members who are members of those institutions—that they object to the name of civil engineers, and they are in accord with Mr. Randolph's suggestion. It seems to be the view of all of those who happen to belong to the other societies, that should we conclude to call ourselves an Institute of Engineers, without the word civil, they would cordially agree to that change.

PRESIDENT COOLEY.—Have you the amendment specifically drawn, Mr. Morgan?

MR. MORGAN:—Only as a motion. It is in the form of a motion to change the name from Western Society of Engineers to the Chicago Society of Civil Engineers. It is in the proceedings of the last meeting, and is as follows: *Resolved*, That Section I of the constitution of the Western Society of Engineers be amended and read as follows: The name of this Association shall be, "The Chicago Society of Civil Engineers"

After some remarks by the President and Mr. Randolph on the subject of offering as an amendment the other name, President Cooley said: If there is no further debate on the subject, we will dispose of it by putting the question.

MR. WASHBURN:—It is natural I presume, that every society, association or whatever it may be, should wish to be called by as dignified, comprehensive a title as they can rightly and justly claim, and I do not think it is a childish wish. If we were to give it a more dignified title, a more comprehensive title, I do not know how the American Society of Engineers will look upon the name if it should be changed to the Chicago Society of Civil Engineers. In the next view,—this society will be more prominently before European engineers than it has ever been before. Probably European engineers know nothing of it now; they will make their first acquaintance with it in 1893. To Europeans our whole continent is known as the

Western Continent; we are the western country; Chicago is somewhat known to them, not so well as New York. The Western Society of Engineers would mean to them the Society of Engineers of the Western continent; the Chicago Society of Civil Engineers would mean an association of Civil Engineers of the City of Chicago,—as members of our own American Society of Engineers might look at it. For the next two years possibly a Chicago Society of Civil Engineers would be best, but Chicago is yet of phenomenal growth. Chicago, it is admitted even by New York people, is destined some day to be certainly the largest city in the country, possibly the center of capital. It will be from Chicago that new interests, new schemes, new plans for development, not only in the far West, but in the Northwest, and in the Southwest will be started. We will be western in the broadest sense of the term. Is it necessary that the city of Chicago should itself be in the West, in order that the Western Society of Engineers should be here? Is it not proper that the men who are more intimately connected with the pushing of schemes on the continent should belong to the Western Society of Engineers? Now one of the arguments that I remember at the last meeting in which this subject was discussed, was that civil engineers was better than engineers. Now in view of the fact that some engineers do not come under the head of civil engineers, the word engineers is better, whatever title is given. Then if Western is better than Chicago, and engineer is better than civil engineer, why make a change? Or if the term Society seems small, does not seem dignified enough, call it the Western Institute of Engineers, but it seems to me that to associate the name Chicago with the Society is not expanding the society in any thing whatever, but is really circumscribing it to citizens of Chicago who happen to belong to this society.

MR. WM. E. WILLIAMS:—It always appears to me that a man must have done something to make him ashamed of his name when I hear that he is seeking to change it. The men who gave this society its name, I understand, discussed this question very thoroughly, and they gave it the name Western with the idea that it was going to represent the engineers of the Western Hemisphere, as the last speaker has said and those men who gave it this name are the men who have done the engineering work which has redeemed this country from the wilderness. I think out of respect to their names we should not make the change. I think we now belong to a society which can point back to members of this society who were charter members, men who made this country what it is. Another point,—the idea that it is necessary to name this society Chicago, so as to enable a man to find it—which has been one of the principal arguments advanced, that unless you gave the postoffice address and the name it would be hard to find this society. Well, probably it will be a good scheme to put in the postoffice address, Chicago, 78 LaSalle Street, but on the other hand, if you simply leave it Chicago—Chicago is growing. The name Western, as I understand it, has outgrown the society—if you are not careful, Chicago will outgrow it in a little while itself, and I would think that would be reason enough for leaving it as it is. There is one point I omitted. I once asked some of the older members and prominent men who helped establish this society why they did not come to the meetings, and one of them said, "When you get over talking about the by-laws and changing the constitution, then I will come up." Now, I think that a pretty good scheme, to do something else besides trying to make changes in the by-laws.

MR. MORGAN:—It appears to my mind that if there are any men in the world who should refuse to be tied to old things, they are civil engineers. I should dislike very much to stand up and claim to be an advocate of the use of a wooden plow because it had been used by my ancestors. Civil engineers should be progressive, and there is very much in a name. Mount Shasta would sound very poorly if we called it Laurel Hill. There is something in a name, and in a descriptive, well-adapted name. In regard to the older members of this society, I have had the pleasure of knowing them since the organization of the society, and I have now in my pocket letters from older members of the society regretting their inability to be present here to-night, but affirming their strong desire that the name of the society should be changed to that which has been suggested.

MR STERN:—It seems to me that no distinction should be made between civil engineer and engineer. The civil engineer is one who directs the forces of nature

to the use and benefit of man, and this includes mechanical engineers, hydraulic engineers, in fact, every kind of engineer. For that reason it seems to me the English society, the Institution of Civil Engineers proper, has named itself the Institution of Civil Engineers, not the Institution of Engineers. The American Society also is the American Society of Civil Engineers. Civil Engineers it seems to me is a broad term, which separates us from military engineers, therefore it seems to me to be the proper term to use for a change of name.

MR. BRENNER asked what proportion of the members are non-residents, to which Mr. Morgan replied: I think that was presented by Mr. Wallace at the last meeting, it was laid out exactly, 66 per cent. were residents in Chicago, I remember.

The president, after asking for further discussion, called upon the secretary to read the resolution, suggesting that to expedite the matter the vote should be decided by a show of hands, the secretary counting the votes.

A point of order was here raised by Mr. Randolph, who presented the following letter:

MR. PRESIDENT:—A number of letters have been received from prominent members of this Society, expressing themselves in favor of the change of name proposed, and regretting their inability to be present at the meeting to-night.

For this, and other reasons, and also for the purpose of obtaining a decision on the measure before the Society, which shall be final and satisfactory, the subscribing advocates of the measure have deemed it best to avail themselves of the provision in the Constitution, namely: Section 2, Article 5, which says, "a letter ballot shall also be taken upon any measure before the Society on demand of five members."

This provision seems to have been incorporated in the Constitution for the express purpose of meeting such circumstances as those existing in respect to this measure, therefore we respectfully demand a letter ballot.

(Signed.) Richard P. Morgan, J.P. Coleman, G. A. M. Liljencrantz, Isham Randolph, Allan Strale, Ethan Philbrick, John F. Wallace.

PRESIDENT COOLEY:—The president has this to say in regard to the point of order. There are two sections of the constitution apparently in conflict with each other. There is one section under the head of amendments which provides specifically as to how amendments are to be made to the constitution, as read by the secretary, that they must first be seconded by a two-thirds vote of the members present at regular meeting. There is another section which has just been read, which says that a letter ballot can be had upon the request of five members. The president will have to construe that in this way: That the specific provision in regard to the amendment of the constitution must be held to be exhaustive of that special form. In regard to the other provision in the constitution which provides for letter ballot on demand of five members, that is intended to apply to such questions as are not usually decided by letter ballot, and that any member desiring the full sense of the society upon a question at issue can have it by making an official request that it be submitted to letter ballot. That is the view of the President on that subject. Now in order to make the question entirely fair, it will be necessary, if you wish to carry your point on letter ballot, to have the decision of the president overruled in the matter and then it would become the law on the interpretation of the society, otherwise the president will act on the procedure which he had in mind, submitting it to the motion for a two-thirds second of the Society—of the members present.

MR. MORGAN:—The reason for pressing that was, to present the question to the Society for a full expression of their feeling. This is an important question, and the specific clause in the constitution provides that two-thirds of the members present might determine on the question of an amendment to the constitution. Now suppose that only nine members were present and four are opposed and five for, that would not make much of a representation of the society. It was with a view to carrying out the spirit that had been manifested from the beginning that that suggestion was made, and the demand was made for a letter ballot. This matter is fairly before the society, all its members, and in good feeling, with the desire that if it would be good for the society to change the name, to do so, and if not, to decline to do so, and the expense of sending out the letter ballot and getting the full expression of the society was considered to be very small comparatively, when considering the importance of the question, and it was with a view to greater knowledge to the members of the society than is contained in the sixth article of the constitution, that this demand was made. That was the feeling that controlled us. It was to have all

the members of the society vote on this question, and as the greater knowledge seemed to be in the 5th article than in the 6th; that was the occasion of making the demand. The measure is before all of the members, and it was because we recognized the equity in the 4th article, because we thought it would make a final determination of the question, that we thought it would be very desirable. Those are the reasons for presenting it in that way.

MR. J. F. WALLACE:—I would like to make an explanation: Upon the subject of changing the name, on first presentation a great many members have been very much opposed. I know when the change was first suggested to me, I did not look on it with favor at all, but the more consideration I gave to it, the more I have been in favor of it, and it struck me that having that question decided before the meeting to-night, where it was uncertain what members would be present, and where a great many who would not be present, might be opposed to it, and where it would require a two-thirds vote of those present to get the matter before the society, that it would be a great deal fairer to put the question before the society on its merits alone, as a letter ballot would do.

PRESIDENT COOLEY:—The President sees no course open to him individually except as in the specific case of questions on amendments that are bound to lie over for two months. If the Society desires to place a different construction on that, personally have no objection whatever; it is only a matter of considering it.

MR. PHILBRICK:—I can see no harm in allowing the matter to come before the full number of the members, and I think it is nothing more than right for the members that are absent, if they wish to vote on this matter. It certainly would get the full consideration of the members of this society; I therefore appeal from the decision of the President.

PRESIDENT COOLEY:—They will have to vote on it if it is adopted by the members of the society present to-night.

MR. PHILBRICK:—If it is voted down they would not get a chance to vote on it.

PRESIDENT COOLEY.—Take two letter ballots?

MR. PHILBRICK:—No, there would be no vote on it to-night. If the decision of the president was the other way, there would be no vote required to-night, but simply a letter ballot on it.

PRESIDENT COOLEY:—I conceive that it might be possible to submit the question here before us to a letter ballot and vote on it again, but two months must intervene; in other words, it is a question whether the determination which is provided here shall be by the whole society or by those present at this regular meeting.

MR. WM. E. WILLIAMS:—This matter has been before the Society about two months; very exhaustive discussions upon it have been published; members have been specially informed that this question would come up to-night to be voted in the regular way. It seems to me if they had had sufficient desire, they would be out in numbers and propose to have it done, and I think this is as fair a representation on this subject as we can get, and we can vote on it as well as we could by letter ballot.

MR. MORGAN:—I believe I have some of the letters addressed to me on that subject. I would like to read one or two of them, with the permission of the Society. (Mr. Morgan here read letters from Mr. Booth, Mr. George S. Morison, Col. Mason, and stated he had a communication from Mr. Corthell and others.)

MR. BRIDGMAN:—Mr. President, begging the society's pardon, I was a little late and was unable to say what I wished to say in the matter. I want to protest against the word civil once more. Of course the membership of this society is composed very largely of civil engineers; in fact all engineers are either civil or military, but all engineers are engineers, whether civil, military, mechanical or whatever they may be, and the term civil engineer has come to be understood as embracing a very well defined branch of the engineering profession Now in this city of Chicago there are a great many engineers who are not civil engineers in the sense of this accepted term recognized as such; they are mechanical engineers and some mining engineers, and a large number of electrical engineers. If this is to be a special society of civil engineers, then of course it is proper that it should be called a society of civil engineers, and those of us who are not civil engineers of course will feel that

we are here merely as listeners; it may be with a certain amount of interest, but we do not care to be called anything else than what we are. We are not willing to lose our general name; and I wish to bring this matter before the society, that if they do incorporate the term civil into their title, they will shut out practically a large number of men who would be an addition to this society.

PRESIDENT COOLEY:—I was saying, it is simply a question of interpretation. If the society is willing to interpret it differently, the President is perfectly amenable to discipline if there is objection to the decision of the chair in the premises, otherwise we shall vote upon the main question, according to the ruling which has been made.

There seems to be no objection to the decision rendered, and all in favor of seconding the motion proposed by Mr. Morgan will hold up their right hand until the Secretary can count the same

A vote was then taken and counted by the Secretary, but there being some objection raised as to the method, Mr. John Lundie called for a ballot

After some discussion and explanation as to the nature and result of the vote, a ballot was taken, and counted by Mr. John Lundie and the Secretary.

The count of the ballot gave the the following result: 23 for, 12 against the resolution. Resolution lost.

SECRETARY:—Gentlemen, the Secretary has not voted. I would like to explain my position. I would not object to see a change made, but I do not like to see it changed to read Chicago, making it more local; I also appreciate the arguments used, to continue the Society a society readily understood to include all classes of engineers, and as described in the constitution. I think that that idea prevails to-day. I agree with Mr. Bridgman, that by selecting the term civil it would exclude some Lines of distinction have grown in this country, and I can not blame some of our members for feeling that it would shut them out. My vote, if I might record it now, would be in favor of a change, but not on the line presented. I have refrained from voting, however.

PRESIDENT COOLEY:—I do not see anything in the proposition that would prevent it from being brought up again at some future time.

MR. MORGAN:—Mr. President, inasmuch as I have made you some little trouble, although I have no doubt it is interesting to the gentlemen present, I wish to say that I feel very grateful for the manner in which the subject has been treated, and the vote as it stood here to-night has certainly justified me in what I did, and therefore I feel exonerated and therefore thank you.

PRESIDENT COOLEY:—The President is only sorry that he could not rule differently. The next business before the Society is the discussion of Mr. Corthell's paper. I believe the title of the paper which was read at the last meeting is, "From the Unsalted Seas to the Briny Deep." That was one title that Mr. Corthell gave it. The President has received no notice of any matter which has been prepared by any other member present, and if any one has prepared anything on the subject it will be in order now. The President would say that he has done so, but he would like to give everybody else a chance before he starts in.

Mr. T. T. Johnston read a short note on the subject, which will be printed in the JOURNAL

The President then called Vice-President Jno. F. Wallace to the chair and read his discussion, shortly after which the meeting adjourned.

JOHN W. WESTON, Secretary.

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OUR VIADUCTS ACROSS THE RAILROAD TRACKS.

BY CARL GAYLER, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read May 20th, 1891.]

During the sixteen years of construction and maintenance of viaducts over the railroad tracks in our city, considerable opportunity has been afforded to collect valuable experience, some of which is probably of sufficient general interest to deserve bringing before the Club. This is the object of this paper, not a description or history of the structures.

The type adopted in the building of the first bridges—on Twelfth and Fourteenth streets—was that of wooden and iron trestles. The latter consists of Phoenix columns on stone foundations, longitudinal girders, iron floorbeams and sidewalk brackets and wooden floor and railing. The design of the ironwork deserves special mention inasmuch as with a minimum amount of material great rigidity has been obtained. Even under the increased loads of the electric roads there is not the slightest vibration or tremor to be detected, whilst the weight of the ironwork in the bridge (width of roadway 20 feet, 2 sidewalks 6 feet wide each) is only 435 lbs. per foot of bridge. The Phoenix columns have lately commenced giving way, the rivet heads breaking off and the columns opening, some from top to bottom. As the metal is only ¼ inch thick, a spacing of rivets of 12 inches was too great.

The ironwork of the north end of the Twelfth street bridge being very much exposed to the smoke of locomotives, which at the Union depot stand directly underneath the bridge, before the trains pull out, afforded a good study of the effect of coal smoke. It has suffered to a considerable extent. The web sheets of the plate girders and floorbeams have been reduced in thickness in places as much as 1-16 of an inch, at other places

no reduction could be measured. The effect has evidently been unequal and is much more perceptible on angles and flange plates, where the metal has been eaten away as deep as ⅛ of an inch.

In such places it seems impossible to sufficiently protect ironwork by paint, and the lesson to be drawn from the above, is that it is very much in the interest of the city to raise the work up as high as possible above the tracks. A clear height of 36 feet as we have on the Grand Avenue bridge, obviates this danger. Wherever an increase of clear height is not feasible, it is good policy to design all ironwork with an additional thickness of metal of ⅛ inch all round.

As not less than six cases of derailments have happened, where cars or engines have knocked out or broken iron columns of Twelfth, Fourteenth and Jefferson avenue bridges, and where in every instance it has been a case of remarkable good luck that no serious accident ensued, this question may be considered to be an interesting one. It may be said that there is no excuse for derailments, that a system of guard rails would remove this danger, but the fact is that derailments do frequently occur and I am not quite sure whether in a great switchyard they can ever be entirely avoided.

Four out of these six derailments were caused through derailed freight cars or freight trains, which were being backed up by the engine in making up a train. This class of accidents can be provided against by building the foundation piers to such a height that the body of the cars cannot strike the ironwork, i. e. to a height of at least 3 feet 6 inches above rail, the force not being sufficient to knock down even a small stone pier. The other two accidents happened through a train running at full speed jumping the track. It is of course impossible to state just what size stone pier could withstand such a shock, but I have the impression that there is certainly no post, built of iron or steel, in existence which would outlive it. We have been told in the discussions of Mr. Theodore Cooper's paper, on American R. R. bridges by several advocates of riveted trusses, that a lattice girder will withstand a derailment whilst a pin connected truss will not. Such statements appear to me unwarranted. If struck by a derailed train, the one is as liable to go down as the other, and so will any structure supported by metal columns whenever the latter comes in the path of a locomotive.

The question of foundation for piers and retaining walls has presented a number of interesting problems.

The streets being intersected by sewers, gas and water pipes, it has been the rule to arch these over in such a manner that the necessary excavation for renewal or repair can be made without injury to the stone work. Where heavy piers are close to a sewer, as for instance on the Eighteenth street bridge, the piers have been carried down to the depth of the bottom of the sewer. It has also been found advisable as a rule to go deeper with all the foundations than the frost line, as the laying of pipes, the building of sewers, changes of the grade of railroad tracks, foundations of new buildings, especially near the retaining walls of the

approaches, &c. may otherwise endanger the foundations. In building the long retaining walls of the approaches, experience has led us to risk settlements in preference to building heavy foundations. Portions of the north approach of 18th street bridge have settled six inches and more during construction, some parts of the approach walls of 21st street bridge nearly as much. In such cases it is much cheaper and answers the purpose as well as to raise and reset the coping stones and point up the walls. This, of course, does not apply to the foundations of the superstructure where settling has to be avoided as much as possible.

The troubles experienced with the foundations of the south main pier of the Grand avenue bridge are instructive enough to be described more fully. This pier is located directly north of Mill creek sewer. The ground was known through borings to be a soft, black clay, easily permeated by water. On account of the proximity to the large sewer it was considered objectionable to use a pile foundation and a footing of concrete 45 feet wide, 80 feet long and 11 feet thick, giving an area of 3600 square feet, corresponding to a pressure of not quite 3000 lbs. per sq. ft. under the weight of the pier itself, and of about 4000 lbs. per square foot under the total load of the structure, was considered as good a foundation as could be obtained without resorting to pile driving. To give as much time as possible for settling, it was also stipulated in the contract, that after the foundations up to the grade line of the street had been built in the fall, no work should be done on the upper portion of the pier until the following spring. In case of settlement, it was intended to make up for it in the thickness of the bed plates after completion of the pier. But one point was not duly considered which soon made itself felt. The concrete foundation of the pier was built up against the side of the sewer, the resistance against settling was therefore greater on the south than on the north side of the pier and a consequent unequal settling of the pier took place, which was a source of anxiety and mortification to the engineer. In building up the pier above ground, the courses of masonry had to be built higher on the north than on the south side, so as to get finally the middle of the top of the pier vertical over the centre of the foundation. Regular measurements of these settlements were taken and the curve plotted, horizontal ordinates representing the time, vertical ordinates the settling. Towards the completion of the pier the curve had very closely approached to a horizontal line. A similar, but lighter curve was observed during the erection of the superstructure and since the completion of the bridge no further settlement could be detected. The north main pier of Grand avenue bridge showed no perceptible settlement, and is an example on a pretty large scale, that a pressure of 4000 lbs. per sq. ft. on our yellow clay is safe.

In regard to floors we have gone through the usual evolution from wooden joists and planking to wooden block pavement on planks carried by steel stringers. Permanent floors seem, after all, on account of their great weight, to be a thing of the far future. As steps in this direction may however be designated the proposed granitoid side walks on the new

21st-St. bridge and the covering of the Forest Park Boulevard bridge over the tracks of the Wabash R. R. with Portland cement concrete arches between steel girders.

The question of the general design of future bridges across railroad tracks has probably, as in other large cities, narrowed down to the following general features:

1. Stone piers at or near railroad tracks.
2. Spans of from 150 to 250 feet length over the tracks.
3. Single intersection trusses carrying the floor. Two trusses, one on each side of the roadway and separating the same from the sidewalks, should always be used in preference to three trusses, which latter arrangement is in use in Chicago. The experience with the Eighteenth Street bridge should forever exclude the cantilever system on account of its lack of rigidity.
4. Short spans on iron columns wherever tracks cannot be laid.
5. The use of mild steel to the exclusion of wrought iron, without, however, increasing the maximum unit strains.
6. Limitation of minimum thickness of metal (except in railings) to ⅜ of an inch. This latter rule is even more important in the case of city viaducts, than for railroad bridges, as they are more exposed to smoke or dirt, and therefore harder to be kept clean and in paint, and as attachments in the shape of brackets or stirrups, may be made at almost any portion of the bridge for carrying pipes, wires, posts, signs, &c.
7. A floor system as substantial as possible; whenever the necessary funds can be obtained, a floor with a concrete foundation should be used, at least for the shorter spans.

THE EDUCATION OF THE MECHANICAL ENGINEER.

By C. H. Benjamin, Member of the Civil Engineers' Club of Cleveland.

[Read April 14th, 1891.]

Oliver Wendell Holmes, being asked when the training of a child should begin, replied: "A hundred years before it is born," and this applies just as much to the embryo mechanical engineer, as to his brothers and sisters,—without he be born an engineer, an engineer he scarce will be, though colleges and polytechnics pour a stream of information through his head.

In one of his latest stories, Edward Everett Hale says of his hero: "The boy had that heavenly gift with tools with which some people are born, and some, alas are not, like this author, and possibly this reader. It is a gift as distinct as that for music or for painting." The rise of many an eminent engineer from a youth of obscurity and privation, through years of struggle and without the helping hand of the school, shows what innate

ability may do without what the world calls education. But what is education? To many it means the acquisition of knowledge, stroing the chambers of the brain with facts more or less systematically arranged, to be brought out on stated occasions either for use or display, as the collector brings out the curios from his cabinet to excite the admiration of beholders. Were this all, it would not so much matter what men studied, and what Spencer calls "the decorative element" of education would have its appropriate place.

But the modern definition of education differs widely from this. The brain is not a storehouse but a workshop, and education not acquisition but discipline, a training of the mind analogous to the athlete's training of the body; we are not so much benefitted by eating the fruit of the tree of knowledge as by the exercise we get in climbing the tree. This cannot be better stated than in the words of Prof. Henry Drummond in an article on Education.

"We now apprehend I hope somewhat more clearly what is, and what is not, to be the aim of an education. We see especially how very different a thing it is from the mere accumulation of information which so many mistake for the goal of a student's life. Information can never make an educated man. To be educated is to be unfolded in all our powers. It shows itself in the individual not so much in positive acquisitions. not in making contributions to the sum of knowledge, but in the attitude and temper of his mind, in the balance of judgment, the large grasp of affairs, the power of concentration, and the genius for hard work. For, again to be educated is not to have stored up knowledge, but to have accumulated a force of thought which we can direct at any time and upon any subject."

And now bearing this in mind constantly, that we are not trying to make out of our boy an encyclopædia, but an active, well-trained force in the world, let us consider how this latter result may be brought about. And first, whatever may be his forte, teach him at home to reason for himself, do not force facts upon him against his will, but put them where he will stumble over them and think he has made a new discovery. Let his methods of acquiring knowledge be as nearly as possible like those he will have to use when he begins to fight his own battles.

In his book on Education, Herbert Spencer emphasizes this especially:

"Any piece of knowledge which the pupil has himself acquired, any problem which he has himself solved, becomes by virtue of the conquest much more thoroughly his than it could else be. The preliminary activity of mind which his success implies, the concentration of thought necessary to it, and the excitement consequent on his triumph, conspire to register all the facts in his memory in a way that no mere information heard from a teacher, or read in a school-book can be registered."

Give him also tools and a chance to use them; he will learn by experience not only the resistance of materials, but the lack of resistance of his cuticle. It has often pained me to see a really ingenious boy laboring, without suitable material on tools, to change some vision of his mind to an

objective reality, with a patience and dogged perseverance worthy of better facilities. Suppose he does not succeed in realizing his ideal, what then? he has learned his lesson, and Edison himself has remarked that success consists largely in finding out the thousand and one "things that won't work."

Our common school system at the present day leaves little to be desired save that teaching by object lessons is not developed as it should be. The kindergarten, the manual training school and the laboratories of the technical school are but different steps in a system of object teaching which should be continuous from the primary school up. Courtlandt Palmer says of them: "The theory underlying them is very simple, viz: that ideas depend on facts, and that to acquire facts the development of the senses is essential. We all know how eager is the observation of all healthy children, and how they love to experiment and contrive. The new education takes advantage of these keen proclivities, and grounds the young in knowledge through the continual application of knowledge.

'When his *hand* 's upon it, you may know
There's go in it, and he'll make it go.'"

The true aim and scope of the manual training school are so persistently misrepresented and misunderstood, that I think a word on the subject will not be out of place here. Too much is expected of the school and its graduates. Whatever may be said by too enthusiastic reformers—I need not remind the practical men before me to-night that the manual training school does not teach trades and does not profess to do so. There are so-called trade-schools in this country and elsewhere, which do profess to teach trades, and how successfully they accomplish this is still an open question. But these are not manual-training schools.

The manual-training school is not alone for the future carpenter, mason or plumber, it is for every boy (and every girl too for that matter) and every boy should go there, just as every boy should go to the high-school, in the latter case to learn to use his brain, in the former to learn to use his eyes and hands.

You do not send your boy to the high-school with the expectation that he will learn of law or medicine, but that his mind may be so disciplined as to enable him to deal successfully with such subjects in the future. So your boy in the manual-training school does not carve wood that he may become a cabinet maker or pound hot iron that he may become a black smith, but does all these things that hand and eye may learn to help the brain, and that he may go forth with these useful appendages trained to do something more than twirl a cane or squeeze an eye-glass.

John Fisher says: "In a very deep sense all human science is but the increment of the power of the eye, and all human art is the increment of the power of the hand. Vision and manipulation,—these in their countless and indirect and transfigured forms, are the two co-operating factors in all intellectual progress." The manual-training school furnishes to the boy who is to enter professional life the only opportunity to acquire that symmetry of development which is true education.

Rev. Washington Gladden in an article in the Century Magazine goes so far as to claim for manual training a distinctively moral influence and says that it affords "a discipline almost indispensable to the right development of character".

Last but not least, manual training gives every boy a true estimate of the dignity of labor.

It should not be expected that manual training will be a substitute for gymnasium work, this is claiming too much. While it undoubtedly affords a relief from ordinary school work, it does not promote physical development, save in a very limited way. Exercises in the gymnasium have one object in view, those in the shop quite another, and both have their place in the true curriculum. Manual training is one of the best feature of modern education but it is not a universal panacea.

In the high school I would emphasize the need of a thorough grounding in English. It would be ludicrous were it not pitiable, to see the blunders in orthography and composition made by students otherwise well educated.

It may be remarked that so far the education of the future mechanical engineer has not been different from that of other boys;—and why should it? These are the foundations and they should be broad. The tendency of boys to slight general studies in their high school course, when preparing for the technical school, should be discouraged. No boy is fitted for American citizenship, not to mention the school of science, who has anything less than a complete high-school training. I would go further than this and say that before entering the technical school every boy who can should lay the still broader foundation of a college education, not so much that he may be a better engineer, but that he may be a better citizen. Narrowing down to the sharply defined limits of a specialty too soon, means a selfish life. It was John Stuart Mill I think, who said: "Know something of everything and everything of something." Not that much time should be devoted to subjects having no bearing on one's life work,—this idea of spending weeks and months on studies which have not the remotest connection with modern life for the sake of the mental discipline, when the same discipline will be afforded by studies of immediate value in practical work, is happily becoming obsolete.

And when we speak of symmetrical development, let us distinguish between that of the athlete which means months of careful training, and that of the devotee of fashion which only means a little cotton padding here and there.

In the technical school there should from the first be broad training in general science and in mathematics as a foundation for the special studies of the mechanical engineer. The work in the chemical and physical laboratories demonstrates new properties of matter to the eager student as no amount of printer's ink can do. The mathematical theorems, while not admitting of such objective illustration, do admit of practical application, and this is the key to the successful teaching of them in a technical school.

Much difference of opinion exists among practical men as to the value of the calculus in actual work, but this is due to a difference in knowledge of the science itself. The calculus is simply a handy tool, and he who disdains to use it is on a par with him who refuses to use a universal milling machine because it is complicated and requires time and study to familiarize one with its use. "A little" calculus "is a dangerous thing," and that is where so many fail. If the drill in mathematics extends over the whole four years with constant application to problems in design and construction, the calculus will be used with the same readiness as algebra and geometry.

The strength of many of the members used in machine construction cannot be figured without the use of calculus, and he who determines them otherwise, either guesses at results or avails himself of the learning of others. An engineer who uses the formulae from Nystrom or Trautwine, without understanding the principles on which those formulæ are based, is as much a quack as the doctor who practices on the strength of a case of medicines and a book, while the fatal results of his quackery are sometimes much more appalling. We want men in the engineering profession who can "give a reason for the faith that is in" them.

We come now to consider the engineering studies, those particular branches which belong specially to the engineering course and to no other, those which are to fit the student directly for his future work.

As no student is capable of foreseeing just what that work will be, the training should be broad and comprehensive, not going too far into minor details, but insuring him such a general command of engineering problems, that he will readily assimilate that special information which actual experience alone can give him. Let not the lines be too sharply drawn in the school between the civil, the mining, the mechanical and the electrical engineer,—those lines are sometimes very dim in the broad plain of engineering practice.

I would make all the work as simple and as concise as possible. The fault with most of our text-books is that they contain too much, and are too abstruse for the average student. A thin fire means complete combustion, while too much fresh coal makes much smoke and little heat. A demonstration which fairly smothers the student, affords little chance for the flame of intellectual effect.

In these, the engineering studies, the utilitarian side cannot be too strongly brought out. There is time in a four years' course to teach in a simple, direct way, the solution of all the primary engineering problems, but there is not time to waste on side excursions into the fields of speculation and doubtful theory. In a word let the instruction be above all practical.

Lectures to students are necessary evils, should only be used to supplement text-books and should be accompanied by printed or stenciled notes, when possible. The notes taken by the student are at best fragmentary and contain more or less of error; they can never be put by him in a form as convenient for future use, as is a printed book, and in many cases will

rarely be referred to again. A text-book, when well arranged and indexed, in good type and copiously illustrated, is on the other hand "a joy forever."

The afternoon work in drawing-room, laboratory and shop should be arranged, as far as practicable to supplement the work of the morning as an object lesson. Prof. Alden of the Worcester Polytechnic, says: "It is by work of this kind that the student is introduced to the field of actual experience, that bookishness, impracticability and inefficiency are in a degree removed before the student leaves the school. Success here vitalizes the whole training, and secures that complete assimilation and personal appropriation of the subjects taught throughout the course, which is the characteristic of the scientific attainments toward which the school should aim."

The instruction in drawing should avoid the merely artistic, and bend toward the practical. Let a good commercial system be adopted and carried out in all its details, and the practicability of the designs and the completeness of the drawings be tested by construction in the shop. Let the difference between a pretty picture and a legible drawing be clearly understood.

It is in this connection that we are led to consider the position of the shop in a technical school, and its relations to other departments. Its functions are not those of the manual-training school, its principal aim not to discipline hand or eye in the construction of elements, but to materialize the abstract idea of the lecture-room and the crude fancies of the drawing-room, and put them to the crucial test of actual construction. The shop is a foretaste of the outer world of hard, unyielding facts. The design may be correctly figured in the class-room, it may make a pleasing picture when drawn, but its attempted realization in wood or iron teaches the student that "there are more things in heaven and earth than were dreamt of" in his "philosophy." Difficulties of construction may entirely nullify ingenuity of design, and the future mechanical engineer must understand not only the laws of the strength and stiffness of materials, but also the limitations of shop practice. The school shop should be a forerunner of the actual shop, and experience there may save the student from much mortification and disappointment in the future.

That the shop may occupy this judicial position in determining the practical value of the instruction given in other departments, it should be a model of its kind, no play shop, but where real work is done by modern methods. All its appointments should be of the best, and, to quote again from Prof. Alden:

"It would be no discredit to such a shop or to the school of which it forms a part, if under the stimulus and in the atmosphere of science, it should produce better machines, adopt leading and improved practical methods, and set higher standards of practical excellence in machine shop practice; if it should make its practice more scientific and its science more practical than the best maaufacturing shops elsewhere."

The shop should be in charge of a man in full sympathy with the work

of the school, but above all a thoroughly practical mechanic. The methods as well as the appointments should be those of a real shop, a careful account of time and stock should be kept, and the student should be made to understand and appreciate the value of these two factors, and the best methods of accurately determining them.

The so-called Russian system of shop-work which consists in resolving each machine process into its elements, and teaching these separately by work on isolated pieces having no value in themselves,—however well it may work in the training-school, is not adapted to the shop of the technical school, where all the processes should be those of the actual shop and where the ethics of machine construction should be the main feature.

I must confess that the Russian system always has seemed to me like a collection of dry bones in a museum, all labeled perhaps and intelligible to the scientist who knows the relation of each bone to some other bone, but a chaos to the average observer, not, as any educational system should be, a living organism.

Let us remember that we are educating an engineer not a machinist or a pattern-maker. He should already have learned in the training-school how to use tools, just as he has learned in the high-school how to use algebra.

He must now learn to design intelligently, and to do this must understand the use of each part, its relations to other parts and to the complete machine, not only on paper, but in the concrete embodiment of the design in wood or metal. Besides all this, giving instruction in shop practice by teaching the elements without showing their relations to each other, is but a repetition of the now discarded practice of teaching letters before words.

Manufacturing articles to sell, however, seems to me impracticable in a school shop. This would limit the variety of the work done, necessarily confining it to a few staples, and thus diminish its educational value. Oftentimes the necessity of completing an order before a specified date would seriously interfere with the main object of the work the instruction of the students. In most technical schools there is a continual demand for apparatus of various kinds, which can readily be made in the shop. The manufacture of laboratory apparatus effects a two-fold result, it stimulates appreciation of the apparatus itself and gives a thorough knowledge of its construction.

After the shop is all that it can be made, we must still remember that there are many things which the student cannot learn there, special features of construction, peculiar methods of doing work, labor-saving processes, which can only be learned in the shops where they exist. Armstrong, the great English engineer, says: "Sir Lyon Playfair declares himself an advocate of including within the scope of technical education the teaching of specific trades and industries. I, on the contrary, say that the work shop and factories, or other places where actual business is carried on, are the proper schools for the learning of such trades and industries." William Mather a prominent English educator speaks the same

vein: "There is no possibility of teaching in a school that sort of knowledge which practical work, carried out on commercial principles * * * * * can alone make one familiar with."

Last but not least in technical education we have the mechanical laboratory, where the experimental data of the text-books may be to a certain extent verified by the student. With the testing machine he determines the physical characteristics of various materials, with the dynamometer the power consumed in various operations, and with the indicator the behavior of steam in the engine cylinder under various conditions, all of them object lessons which fix indelibly in his mind the statements of the books.

I think there is a tendency in some schools to slight this simple use of the laboratory for the instruction of students, in favor of so-called original investigations in new directions, which shall, when published, increase the reputation of the ambitious professor, however little they may be understood or appreciated by the students who do the greater share of the work.

" 'Tis pleasant sure to see one's name in print,
A book's a book, although there's nothing in't."

The primary object of a mechanical labaratory as of other parts of the school equipment, is to teach students, and any use of the laboratory which does not further this object is a false one. Let the student learn the ordinary application of the apparatus thoroughly and well. He has not time and usually not the ability to astonish practical men with new discoveries in science, and even his graduating thesis need not be disparaged for containing nothing new, provided it contains nothing absolutely untrue. Modesty in a graduating thesis is an evidence of merit.

In bringing to a close the school education of the young engineer he must be made to feel that he goes forth from the school still a learner, not a teacher or a prophet, and that the college and the polytechnic are but fitting schools for the great university of practical experience where alone can he continue his education.

To sum up the whole matter I would say let the education be broad and liberal but always practical, practical leading up constantly to the level of actual performance, that when the student leaves school he may not find the transition too abrupt, that he may not find a "great gulf fixed" between the methods to which he has become accustomed and those of the shop and the factory.

Scientific education is what has raised engineering from a trade to a profession, and led the world to put a true estimate on the dignity of labor. In the words of John E. Sweet: "Let us hope, if the tide of human progress is sweeping on towards a more useful education, that the day may not be far away when he who knows what to do and how to do it will be regarded as the equal of him who only knows what has been done and who did it."

DISCUSSION.

Mr. Warner:—Just a few words. We have all had some observation regarding engineers, and one thing which occurs to me is that we have found so many young engineers who go out thinking they do know it all, and there is rather a disadvantage in the engineer's education from the fact that as he leaves the technical school he has no University to attend, no post-graduate to attend, consequently the young student goes out thinking he is prepared to do anything. I will only repeat what occurred to a gentleman whom I knew in visiting a large manufacturing establishment in Pottstown, the superintendent of which, had a thorough technical education which was supplemented by 20 years practical experience. This gentleman whom I knew was visiting him, and a young man came in and asked to see the superintendent. He excused himself for a moment to attend to his visitor, and after a few minutes he came back and said, "What do you think that fellow wanted? Well, he wanted my place. He just graduated from the Institute of Technology and wants to come in here and take charge, and he wants to know how long it will be before he can take entire charge." I have found young men with just about that idea.

Mr. Wellman:—I agree substantially with Professor Benjamin. I think the young engineer should have some practical with his theoretical training.

Mr. Swasey:—I was especially interested in the first part of Prof. Benjamin's paper, that it is no use for a man to commence a certain calling unless it is really born in him. I believe in that. We all hear about men being called to preach. Now I believe a good engineer or a good mechanic is just as much called to work in that line as in any other. I remember an instance where a boy came in one day and said he wanted to learn a trade. I asked him what he wanted to learn a trade for. O, he said, he thought he would. I asked him if he had thoroughly made up his miud he wanted to be a machinist. "Well, no," he said, "I really have not made up my mind whether I want to be a lawyer or a machinist." I told him I thought the first thing he should do was to go home and think it over a little himself; he could probably tell after a while, but any way he would know more about it if he would think of it a little more. I think there is a great deal in that. We see it all through life, how one must be especially adapted for the line of work he takes hold of. We see that with a great many men it is uphill work from one year's end to the other, unless they have a natural adaptation for their work. We all know it is no use for some people to go to school, for they would not learn much if they did, and so it applies to every other line.

Mr. Gobeille:—I would ask Mr. Swasey if there is not such a thing as being too inventive.

Mr. Swasey:—The jack-at-all-trades does not amount to any thing, but there is a certain class of men who are what we call inventive. They are tinkers, as we call them. They generally have a little shop about 5 or 6 feet square and they fill a very large place in society, where you

can get anything mended that you take there, and I think they are very valuable people, but they do not generally grow up to be eminent engineers, the leading engineers of the country or any thing like that. Yet they have their place to fill, and it is quite a good one.

PROF. BENJAMIN:—I would say just a word in regard to what Mr. Swasey said last, that a great many teachers have made the remark that if there was anything they hated it was a boy who was brought by a doting parent, regarding whom it was said that he was ingenious, for such a boy was invariably a nuisance and never amounted to anything in the school and never got settled down to work.

DIAGRAM FOR APPROXIMATE SEWER CALCULATIONS.

By EDGAR S. DORR, MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read October 15, 1890.]

The object of this diagram is to enable the person using it to arrive at a tolerably correct idea of the size of sewer required in any particular case as soon as he knows the principal facts concerning it, that is:

1st, the size and character of the district to be drained, and;

2nd, the fall which is available for the sewer.

To accomplish this, two sets of curves are plotted with the same vertical and horizontal scales.

The first set, those springing from the lower left-hand corner and going toward the right upper corner are designed to give the flow that may be expected from any given area.

The ordinates of these curves are cubic feet per second.

The abscissas, written along the top, are the number of acres drained, as for example:

100 acres gives 62 cubic feet per second flow, to be carried by the sewer.

There are five of these curves corresponding to that number of degrees of steepness of surface, namely:

One for flat districts, the general inclination of which is 5 ft. per 1000.

Another for steeper slopes, 10 per 1000.

Another for 20 per 1000, then 50 per 1000, and 100 per 1000.

The curves are plotted according to the interpretation of the Burkli-Ziegler formula found in Gray's Providence Report of 1884, using the table of coefficients which he gives there, and giving the value 1 to the factor r, the rate in inches of rainfall per hour; or, in short, the curves give the flow which may be expected from any given area, from a rainfall of one inch per hour, falling at a uniform rate.

A line is also plotted for reference, representing the old assumption of

an inch rainfall per hour, one half reaching the sewers, or at the rate of one-half cubic foot per second per acre.

For example: 100 acres, the general pitch of the surface of which is 5 ft. per 1000 yield 30 cubic feet per second; if its slope is 20 per 1000, 42 cubic feet; if 100 per 1000, 62 cubic feet.

The second set of curves, those going from the left downward toward the right represent the capacities of sewers of various sizes, at various inclinations.

They refer to the same vertical scale of cubic feet per second; and the horizontal scale is in terms of the horizontal component of the angle of inclination, or the number of feet horizontally in which the sewer falls one foot vertically, the ordinary terms in which the pitch of a sewer is described, as 1 : 500, 1 : 1000, etc.

For example: A 4 ft. circular sewer, running 3 feet deep, at a pitch of 1:150 carries 105 cubic feet per second.

If the sewer is running under a head, the slope of the hydraulic gradient of course, must be taken, not the actual pitch at which the sewer is built.

The whole operation then is as follows: Suppose we have to drain 200 acres lying at a general slope of 20 per 1000, and our outlet sewer has a fall of 1:500; then we find that 200 acres at 20 per 1000 yields 70 cubic feet per second; and looking on the sewer curves we find that at 1:500 a 4 ft. 6 in. circular sewer running 3.25 ft. deep carries 74 cubic feet per second, this then is the size indicated by the diagram.

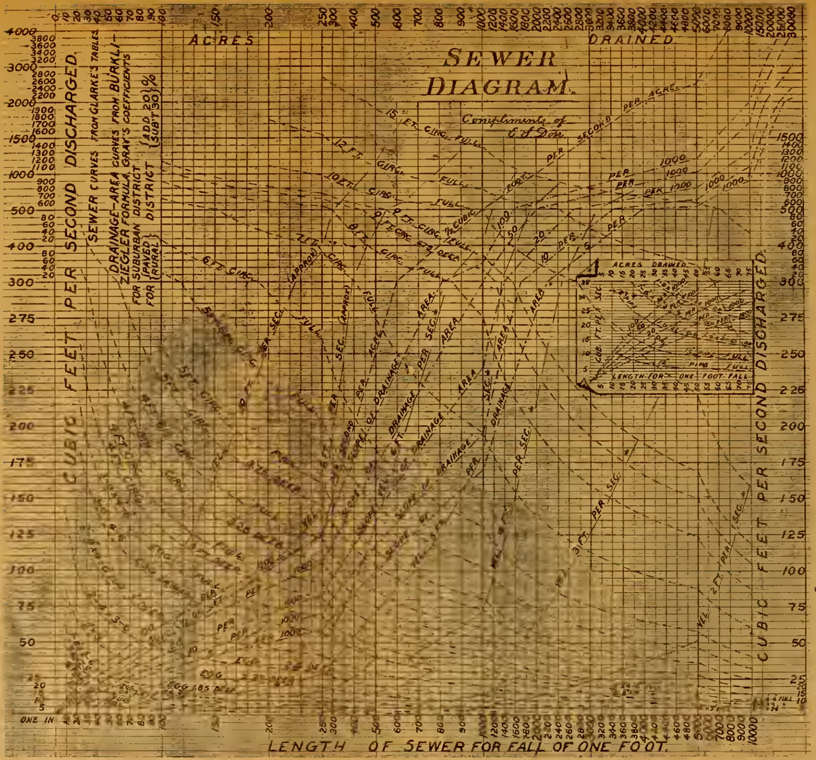
The angles in the curves are due to changes in scale, both horizontal and vertical. It is not practicable to plot them or any one scale without making them either illegible at one end, or stretching them out to an unmanageable length at the other end. If plotted on any one scale, the curves would of course be smooth sweeps.

It will be noticed that the scale of acres drained at the the top, and the scale at the bottom showing the pitch of the sewers, are made to correspond, as for example, the same vertical line indicates 500 acres on the drainage-area curves, and a fall of 1:500 on the curves of capacities of sewers. This is done to avoid mistakes in the use of the diagram. Although the scales at the top and bottom indicates different things and refer to different sets of curves, it does not make any difference which a man uses.

The note in the corner states that these Drainage Area curves are calculated for suburban districts; if the district is closely built upon and paved, an allowance of 20 per cent. should be added; if in a rural state 30 to 50 per cent. should be subtracted.

The diagram is particularly handy in discussing schemes of sewerage, the sizes of sewers required by different plans can be compared and the results of proposed changes or modifications can be seen in a moment, without going through tiresome calculations.

Another application is to show about what a sewer carried under some unusual conditions, when completely submerged, for instance, and discharging under a very small head.


SEWER DIAGRAM.
Compliments of E. J. Dow.
ACRES DRAINED.
CUBIC FEET PER SECOND DISCHARGED.
SEWER CURVES FROM CLARKE'S TABLES.
DRAINAGE-AREA CURVES FROM BÜRKLI-ZIEGLER FORMULA, GRAY'S COEFFICIENTS
FOR SUBURBAN DISTRICT (PAVED) (ADD 20%)
FOR DISTRICT (RURAL) (SUBT 30%)
CUBIC FEET PER SECOND DISCHARGED.
LENGTH OF SEWER FOR FALL OF ONE FOOT.
ACRES DRAINED
LENGTH FOR ONE FOOT FALL
PER SECOND PER ACRE
15 FT. CIRC. FULL
12 FT. CIRC. FULL
10 FT. CIRC. FULL

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The sewer curves are plotted from Clark's Tables. They agree very closely with the Kutter Formula taking N as .013 in the medium sizes of sewers; in the smallest the diagram indicates quantities 10 or 12 per cent larger, and in the largest sizes about the same per cent smaller than Kutters Formula. Of course, any one who thinks that is not accurate enough is at liberty to figure it finer, (the diagram would still be an aid in approximating the size), but when we consider the uncertainty in which the other end of the problem is still involved, that is, the proper rate of rainfall and discharge from any given area, these percentages are really insignificant.

I would say in connection with this subject, that I have tried to get some idea of the proper rate of rainfall which should be provided for in the vicinity of Boston, by plotting the observed rates of rainfall for different periods of time on a diagram, after the manner adopted by Mr. Kuichling and explained in his article called "The Relation between Rainfall and Discharge of Sewers in Populous Districts," a little pamphlet with which, no doubt, most of us are familiar. The data were obtained from the records made by Dr. Desmond FitzGerald's automatic rain gauge at Chestnut Hill Reservoir, covering a period of ten years.

The results show that for small areas we should provide for much larger rates of rainfall than we have been in the habit of doing, for instance, for areas of such a size and slope that the water from all portions may reach the outlet in one hour or less the diagram indicates a rate of 1.6 inches per hour; for areas in which the same condition may occur in one-half hour, a rate of 2 inches should be provided for.

The difficulty which is encountered in trying to reduce these principles to practice or to a formula, is in establishing the relation between the size of a drainage area and the time necessary to concentrate the flow of the sewers at the outlet.

It would seem to call for the invention of a new formula in which the size and slope, and the dimensions, longitudinal and transverse of the district should be factors. This suggestion offers a field for some one to do a great and good work in evolving such a formula.

SKETCH OF THE TOPOGRAPHICAL SURVEY OF MASSACHUSETTS BY THE UNITED STATES GEOLOGICAL SURVEY, 1884 TO 1890.

By E. W. F. Natter, C. E.

[Read before the Boston Society of Civil Engineers, February 18, 1891.]

In 1830 the Legislature of Massachusetts required the various cities and towns to file with the Secretary of State accurate plans of their territory on a scale of $^1/_{19000}$ and also provided for a trigonometrical survey of the State to be used as a basis for combining the various local surveys into a state map.

The trigonometrical survey was executed by Mr. Simeon Borden and was very finely done; it was completed in 1846.

The town surveys were made by local surveyors and far from accurate, so that the compilation of the State map required a large amount of adjustment and additional field work.

The map was finally published in 1844 on a scale of 2½ inches to the mile, and with corrections and additions made by Mr. H. F. Walling has been used up to the present time.

In 1883 the U. S. Geological Survey determined to make a topographical survey of Massachusetts and in order to secure the benefit of this, and also to secure a more detailed map, the Legislature of Massachusetts appropriated $40,000 to be used by the U. S. Geological Survey in making the map, and three commissioners were appointed to supervise the work for the State. Under this arrangement the State received the original sheets of the survey scale $^1/_{30000}$ and the U. S. Geological Survey retained the engraved copper plates.

The State has had transfers made from these plates onto stone and an edition of the map printed in 54 sheets which are now for sale.

The methods used in making the survey varied considerably with the different parties.

The topographical work was based on the triangulation of the U. S. Coast and Geodetic Survey and the Borden Survey which was all recalculated by the Coast Survey and adjusted to conform to their latest standards. Some additional triangulation was furnished by the Coast Survey.

In plotting the topography the plane table was largely used, each sheet covering 15 minutes each, of latitude and longitude. A large number of points were determined by intersections, and elevations by vertical angles and the barometer.

The actual topography was filled in between these points by plotting of traverse surveys of roads etc., or from local surveys reduced to the scale of the new map and fitted in between points determined by the plane table.

The use of these local maps, some of them of doubtful accuracy, was necessitated by the requirement that the cost of the work should not exceed about $10.00 per square mile.

Along the coast the original sheets of the Coast Survey were reduced to the scale of the new map by photography and transferred directly onto the new sheets with such changes as had occurred since the original surveys, and this part of the new map is the most accurate.

A section of the south-eastern part of the State which is quite flat and heavily wooded was surveyed without the use of the plane table and apparently without reference to the few triangulation points which were located there as they do not all appear upon the original sheets.

As a rule the contouring is the weakest part of the whole map although advantage was taken of all levels and profiles, railroad, water-works and municipal, which could be obtained as well as the use of vertical angles from plane table and transit stations and barometric observations, but a vast amount had to be sketched in by the eye.

The accuracy of the sheets varies very much even in those made by the same person. Sheets made in 1888 are as a rule much more accurate than those made in 1885.

The published sheets are on a scale $^1/_{62500}$, about 1 inch to a mile, too small a scale and too inaccurate to lay out engineering work by, but still valuable in indicating the character of the country.

Existing errors on the published sheets are not all due to the topographer, as from 30 to 50 per cent of the errors which have been pointed out on the published sheets have been found to be correct upon the original sheets.

Wooded areas and isolated houses were plotted upon the original sheets but were not engraved in order to avoid confusion.

This map with all its errors is a vast improvement upon its predecessor and is expected to demonstrate to the people at large the value of a map which will accurately delineate the topography of the State.

The State Commissioners are now engaged in the work of determining the location of the territorial boundaries of the Cities and Towns by a system of triangulation. These lines were not delineated on the topographical sheets and the attempt to plot them there shows very many of the inaccuracies of that work.

In prosecuting this work it becomes necessary to establish very many auxiliary stations in prominent locations and when it is desired to make an accurate map these stations will be very valuable.

PLANE TABLE METHODS USED BY THE UNITED STATES GEOLOGICAL SURVEY IN WESTERN MASSACHUSETTS IN 1886.

By Louis F. Cutter, Member Boston Society of Civil Engineers.

[Read February 18, 1891.]

In 1886 the topographical work of the Geological Survey in Massachusetts was carried on in three different ways in different parts of the state. In the flat wooded country in the South East the detail depended wholly on traverses made with compass and telemeter, controlled at rather wide intervals by transit triangulation, in the hilly country west of the Connecticut the plane-table was used to the exclusion of traverse methods, and in the region about Boston the plane-table and traverse methods were combined. The second, or plane-table method without traverses is the one which I am about to describe.

The map of Massachusetts is published in atlas sheets on a scale of 1 : 62500 or about 1 inch to a mile. Each atlas sheet covers 15 minutes of latitude and 15 minutes of longitude, or about 17 miles from north to south and about 13 miles from east to west. The contour interval is 20 feet. For convenience and accuracy in working, the plane-table sheets were made on a scale of 1 : 30000 or 2500 feet to an inch, a little more than double the publication scale. As a plane-table sheet representing an area of 15 by 17 miles on a scale of 1 : 30000 would be unwieldy, the northern and southern halves of each atlas sheet were surveyed on separate plane-table sheets, each of which therefore represented an area of about 110 square miles. The work on each plane-table sheet was assigned to a sub-party usually consisting of two men and supplied with a horse and buggy and the necessary instruments. In 1886 there were six such sub-parties in Western Massachusetts, all under the leadership of Willard D. Johnson, Topographer in charge, and making monthly reports to him. Six plane-table sheets were thus kept going at once.

The horizontal work was based on the located points of the Coast and Borden Surveys, and the hypsometry on the elevations given for the Borden points and on elevations furnished by the railroad profiles. The smallness of the amount of money available rendered it impracticable to carry the triangulation any finer by the transit, or to run lines of base levels. Therefore the plane-table triangulation had to be carried unchecked over the wide intervals between the Borden points, and in one case, where a sheet contained only one Borden point, the other end of the base line for the plane-table work on that sheet was furnished by a point located by plane-table triangulation near the edge of the next sheet, and transferred by divides to the sheet in question.

The plane-table was used as a triangulating instrument almost exclusively: no telemeter was used, and traverse methods were hardly ever employed. A main plane-table triangulation consisting of large well-shaped triangles was first carried across the sheet, checking if possible on points located on the adjoining sheets. The stations were marked with large signals visible from long distances, which were especially useful in carrying on the subsidiary plane-table triangulation which followed.

In carrying on the subsidiary triangulation experience showed that the fascinating "three point" method was not generally economical, and that it was better to partially explore the country, plan out a system of triangulation, and erect temporary signals before attempting the subsidiary triangulation. If the money available had been sufficient to permit the occupation of a greater number of plane-table stations, and to allow of the surveying of the detail to a greater extent on the plane-table sheet, instead of by the less accurate method about to be described, this doubtless would not have been the case.

In the course of both the main triangulation and the subsidiary, a great many lines were drawn to houses and prominent natural objects such as prominent trees, or rocks, hill tops, &c., and lines were also drawn to road crossings and bends in roads. When possible these lines were intersected and the objects located by lines drawn to them from another station, but even a single line to an object was often useful, as its location in the other direction could perhaps be approximately determined in other ways. Indeed lines were often drawn when there was no hope of obtaining a location by intersection; for instance, lines tangent to bends in a road or river, or lines drawn to cols or to changes of slope in the profile of a ridge.

The objects to be represented on the map were railroads, public roads and important private roads, inhabited houses, rivers, brooks, ponds, and swamps, the wood outlines, and the relief. The wood outlines were not intended for publication. The unsatisfactory method above referred to which poverty compelled us to adopt for the mapping of the detail of the roads and the objects near them depended on the existence of the old town map contained in the county atlases. The roads on these maps had apparently been surveyed by compass and "wheelbarrow", and the detail of the roads was in many cases pretty accurate, but in long distances the distortion became very great. In some cases this distortion appeared to be intentionally produced in order to make the towns fit into the pages of the county atlas. Now if objects such as houses or roadside trees could be located by plane-table intersection at short intervals, say 1 or 2 miles, along the roads, and the roads from the town maps, enlarged or reduced to the proper scale, adjusted in short pieces between these points, the generally excellent detail of the old maps (as far as the roads were concerned) would be preserved, while the distortion in long distances would be avoided. This then was the method adopted. But first the detail of the town maps had to be verified, and, if wrong, corrected. For this purpose the town maps were copied on white paper on the working scale of 1 : 30000, and carried on a lapboard while the topographer drove over every road

and made corrections where he found mistakes, (measuring distances by the revolutions of the buggy wheel when necessary), and crossed off all abandoned roads and houses, and put on the new houses and roads, and saw that each house was shown ot the right distance back from the road. At the same time the topographer sketched the ponds, brooks, wood outlines and approximate contour lines, as far on each side of the road as they could conveniently be observed. It was found that the brooks and ponds as shown on the old maps were exceedingly inaccurate, some of the smaller ponds being shown 3 or 4 times as large as they should have been. During this "road sketching," as it was called, barometer readings were taken at all prominent changes of slope in the road. These readings were afterwards adjusted between frequent readings at known elevations by a rather complicated method.* Thus elevations were established at short intervals along the roads at a very slight additional expense.

By doing the road sketching after the main plane-table triangulation, but before the subsidiary triangulation, an opportunity was furnished for the planning out of the latter and erection of temporary signals before mentioned, and it was in the combination of these two processes, road sketching and preparation for triangulation, and also in the fact that the road sketching gave the topographer a familiarity with the country which greatly increased his efficiency in triangulation, and especially in identifying points for intersection, that the economy of this method over the three point method consisted.

The relief and other features immediately around plane-table stations, and in those regions which could not be sketched from the roads, were sketched on the plane-table sheets. Thus it happened that the contours in the valleys were usually obtained from the sketching on the town maps, and the contours of the hilltops from the sketching on the plane-table.

Differences of elevation between located points were obtained by vertical angles taken with the alidade, the horizontal distance being measured with a scale on the plane-table sheet. Thus, starting with the Borden points or railroad elevations, a great many points were determined in elevation throughout the sheet, and these furnished the basis for the barometric work.

The accuracy of any map depends on two things; first, on the accuracy of the sketching upon which the representation of the detail ultimately depends however minutely the instrumental work may be carried out, and second on the accuracy, frequency and efficiency of the "control" or geometrical skeleton on which the sketching hangs. By the frequency of the control I mean the frequency of the points where the sketching rests upon it.

It is difficult to get any measure of the accuracy of the sketching of the Western Massachusetts work, because there is no check upon it except at the place where two sheets join. I can say however that in adjusting the borders of the South Chesterfield sheet with the four surrounding sheets I found that the general form of the country as shown on the different

*See "Use of the Aneroid Barometer in Western Mass. by the U. S. Geol. Survey." Technology Quarterly, Sept., 1887.

sheets often agreed pretty well, but there were a few astonishing discrepancies, notably in the case of a railroad where there was a disagreement of nearly ½ mile as to the place where it crossed from one sheet to the other. Such errors as this, however, must be ascribed to an insufficient frequency of control rather than to inaccurate sketching.

Of the accuracy of the control it is more easy to make a statement, as it often happened that the same point was located by plane-table intersection on two adjacent sheets. For instance the plane-table triangulation of the South Chesterfield sheet was started from a rather short base line (about 4 miles), one end of which was furnished by a Borden (or Coast Survey) point and the other by a point located by plane-table triangulation on the North Chesterfield sheet, and transferred by dividers. It was found, after the end of the field season, that a certain church spire, not visible from either end of the base line, had been located by the Coast Survey. It happened that this same church spire had been located by plane-table intersection in the course of our subsidiary triangulation. The spire was plotted on the plane-table sheet from the Coast Survey co-ordinates, and the distance between the Coast Survey location and ours was found to be about 1-50 of an inch, corresponding to less than 1-100 inch on the publication scale. I believe there were no common points located on the South Chesterfield sheet and the sheet to the east. Two points were occupied as plane-table stations by us and by the sub-party to the south, and though the discrepancy in location was perceptible it was very small. On the west, one common point was located by intersection and the disagreement was almost imperceptible. The above results show that plane-table triangulation can be carried over wide stretches of country and even from sheet to sheet, without any large errors.

It is impossible to judge of the accuracy of our vertical angle work by a comparison of the elevations of the same point found by different subparties, for there were strong indications that some of the elevations given for the Borden points which we used as bench marks, were in error by an amount greater than any error which we could make in carrying a line of vertical angle elevations across a sheet. A comparison of the results obtained by different series of vertical angles starting from the same point and checking on another, indicates that the greatest error of any vertical angle elevation with reference to the starting point used for that sheet is probably not more than 10 or 12 feet, but there are probably much larger errors in the absolute elevation above sea level, owing to the errors in the elevations given us to start from. Thus the utility of the map is sadly decreased for want of a system of base levels.

The precision of the barometric work can best be judged by a comparison of the results obtained by different observations at the same point. On the South Chesterfield sheet and the Southeastern corner of the Granville sheet there were 112 points where more than one barometric observation was taken. At these 112 points 270 observations were made, the number of observations at each point varying from 2 to 5. A weighted mean of the results of the observations at each point was found, and also the deviation of the result of each observation from the weighted mean. The

average of all the 270 deviations was 5.26 feet, and the greatest deviation 36 feet. The following table shows the distribution of deviations of different magnitudes:

Magnitude of Deviations. (Feet).	Number of Deviations.	Per cent. of Whole Number of Deviations.
Greater than 39 feet	none	0.0
35 to 39 "	3	1.1
30 " 34 "	none	0.0
25 " 29 "	2	0.7
20 " 24 "	7	2.6
15 " 19 "	4	1.5
10 " 14 "	31	11.5
5 " 9 "	55	20.4
0 " 4 "	168	62.2
	270	100.0

It will be seen that 94.1 per cent. of the deviations are less than 15 feet.

As a measure of the frequency of the geometrical control, the number of points located, or determined in elevation per square mile (that is, per square inch of the published map) may be given. It should be remembered however that the usefulness of the control depends not only on the number of the located points but on their distribution and on the efficiency of the individual points in controlling the sketching, and therefore, in comparing the number of locations per square mile on a plane-table sheet with the number per square mile on a sheet mapped by traverse methods, it should be remembered that the plane-table gives a more uniform distribution of locations than the traverse, and that the plane-table locations are usually chosen for their usefulness in controlling the sketching, while a large proportion of the traverse stations are useful merely to carry along the line.* A statement of the amount of control per square mile on the Southern half of the Chesterfield sheet, and on the Southeastern corner of the Granville sheet is given, together with an expense account, in the following tables. The amount of control on both sheets and the expense of the Granville corner are obtained from records made at the time, but some of the items of expense on the South Chesterfield sheet are put in from memory and guess, so that the results may be slightly in error. The cost of supervision and administration is not included in the statement.

A discussion of this matter by Henry Gannett may be found in *Science* for July 1887.

Control, and Cost for Field Work of the Southeastern Corner of the Granville Sheet. (Area 25 square miles.)

Surveyed by a sub-party of two men in 16 days, on 4 of which outdoor work was prevented by bad weather.

	Total	Per Sq. Mile. (Av).	Per Day. (Av).
Area Mapped (Sq. Miles)	25		1.56
Plane-table stations occupied	16	0.64	1.00
Other plane-table locations	110	4.40	6.87
Total plane-table locations	126	5.04	7.87
Linear miles of roads verified and sketched.	58	2.32	3.63
Vertical angle elevations	35	1.40	2.19
Aneroid elevations	200	8.00	12.50
Total elevations	235	9.40	$14.69
Cost for Salaries	$ 54.73	$2.19	3.42
" " Transportation	40.60	1.63	2.54
" " Subsistence	17.75	0.71	1.11
Miscellaneous expenses (estimated)	3.00	.12	.19
Total Cost of Field Work	$116.08	$4.64	$7.26

The additional cost of the office work was about $2.28 per square mile.

The average number of plane-table locations made from each station was 6.87.

Items of Cost of Field Work on the Southeastern Corner of the Granville Sheet. (Area 25 square miles).

(From records made at the time).

Salaries:		
1 Field Assistant in charge 17-30 month at $50	$28.33	
Other Field Assistants (in all)	26.40	
		$54.73
Transportation:		
1 Horse and Buggy 17-30 month at $50	28.33	
Feed and care of horse	12.27	
		40.60
Subsistence (of field asst. in charge)		17.75
Miscellaneous:		
Material, supplies, stationery, repairs, and depreciation of instrument about		3.00
Total		$116.08

CONTROL AND COST FOR FIELD WORK OF THE SOUTH CHESTERFIELD SHEET. (Area 110.45 square miles.)

Surveyed by a sub-party consisting sometimes of two men and sometimes of one man, in 122 days, including those days on which out-door work was prevented by bad weather.

	Total.	Per Sq Mile. (Av).	Per Day. (Av).
Area mapped (Sq. Miles)	110.45		0.91
Plane-table stations occupied	64	0.58	0.52
Other plane-table locations	690	6.25	5.66
Total plane-table locations	754	6.83	6.18
Linear miles of roads verified and sketched	about 220.7	1.99	1.81
Vertical angle elevations	277	2.51	2.27
Aneroid elevations	1132	10.24	9.28
Total elevations	1409	12.76	11.55
Cost for Salaries	$315.00	$ 2.85	$ 2.58
" " Transportation	349.60	3.17	2.87
" " Subsistence	190.15	1.72	1.56
Miscellaneous expenses (estimated)	30.00	0.27	0.25
Total cost for Field Work	$884.75	$ 8.01	$ 7.25

The additional cost for office work was about $1.80 per square mile.

The average number of plane-table locations made from each station was 10.78.

ITEMS OF COST OF FIELD WORK ON THE SOUTH CHESTERFIELD PLANE-TABLE SHEET. (Area 110.45 square miles.)

(Partly from records and partly from memory and estimate).

Salaries:

1 Field Assistant in charge 4½ months at $50	$225.00	
Other Field Assistants (in all) 3 months at $30	90.00	
		$315.00

Transportation:

1 Horse and Buggy 4½ months at $50	225.00	
Feed and care of Horse 137 days at $0.80	109.60	
Express and cartage (about)	15.00	
		349.60

Subsistence:

1 Field Asst. in charge 137 days at $0.95	130.15	

Other Field Assistants (in all) 60 days at $1.00...... 60.00

190.15

Miscellaneous:

Material, supplies, stationery, repairs and depreciation of inst. (estimated)................. .... 30.00

Total................. ....$884.75

In regard to the expense, it may be well to say that our instructions were to keep the work up to a certain rather elastic standard of accuracy, which would be very difficult to describe, but of which we all had a reasonably definite idea. We were not limited to any particular cost per square mile, but it was commonly understood that we were expected to keep the cost of field work below $10. per square mile, and the system of monthly reports induced a very lively competition as to who should make his map the cheapest.

DISCUSSION.

PROF. W. S. CHAPLIN said that the chairman had made an unfortunate choice in calling on him first, as he has had no opportunity of testing the accuracy of the survey practically. He thought that criticism was disarmed by the papers to which the society had had the pleasure of listening. It appeared that the surveys and maps had cost less than $5 per square mile. While for such a price a map sufficiently good for geological purposes, could be made such a map would be of little use to engineers. It appeared that the new survey depended on the old triangulation and the old maps, and he did not see that for engineering purposes the new map was a great improvement on the old one.

The new map would not greatly aid in making a better one. Supposing that to survey the state and make an entirely new and satisfactory topographical map would cost $20.00 per square mile, he did not believe that having the present map to assist the price would be reduced $5 per mile. He feared that the existence of the present map would put off the time when a really complete and accurate map could be made. The present map must be regarded as a sketch map, which, considering the low cost to the state and the extremely small pay received by the surveyors, was in every way creditable. He did not wish to be understood as in any way condemning or criticising the officers and employees of the survey. They had done their work in a most pains taking and economical way; but he did criticise the policy of spending money on a map which was necessarily imperfect and must soon be replaced by a better one.

MR. F. P. STEARNS:—I fully agree with Prof. Chaplin as to the desirability of a more accurate topographical map of the state, but I cannot agree with him in his very low estimate of the value of the present map. I have used it very extensively in connection with preliminary examinations for water supplies and sewerage in the state and hardly know how I

should get along without it. It is obvious from what we have heard to-night of the methods of making the map and its small cost that we should not expect too much of it, and I am surprised to find the work as accurate as it is in most instances, when the small expenditure is considered, although in some places I have found the map very defective. As an illustration of the good and bad features of the map, I may instance the last two places at which I have used it. Before going to Orange a few days ago I sketched upon the map the watersheds of several ponds and streams which might be available as sources of water supply, and I did not in any case find occasion to change the location of these watersheds from an examination of the ground. Moreover, the elevations corresponded as nearly as could be expected with those obtained by a barometer which I carried with me, and in one instance, they agreed with actual levels. The size of one pond as measured from the map was 96 acres, while by actual survey it contained only 60 acres. In this instance, two or three hours office work with the aid of the map gave me much light as to the relative merits of all the sources which could be made available for the water supply of this town.

A few days before going to Orange I went to Haverhill on a similar errand and with similar preparations. In this case I found the map very misleading. Kenoza Lake was indicated as a body of water having no outlet, and the map indicated that the divide crossed a valley north of the lake about two-thirds of a mile from it. Upon reaching the ground I found a large brook flowing from the lake, which required the divide to be moved two-thirds of a mile southerly to the edge of the lake. In one other place near the lake the divide was half a mile from where it was indicated upon the map.

I have found one case where the elevation of a pond of considerable size was 100 feet in error, and another case where a valley between two mountain ridges was shown 300 or 400 feet too low. In my experience with the map these large errors are the exception, but I mention them to show that the map should not be used for any final determinations, even for preliminary work, without verification by an examination of the ground. I have not had occasion to plot upon the map any actual surveys and therefore know nothing as to the amount of distortion.

I think it is greatly to be regretted that the scattered houses have been omitted from the published sheets as they are a valuable aid in determining one's position on country roads.

There is another practical defect as the maps are published that they are not numbered. They should be, and have corresponding numbers on the index sheet so that they can be kept in order in the portfolio and readily found.

Mr. M. M. Tidd:—I took considerable interest in the publication of this map anticipating that it would be of much assistance to me in preliminary plans for water-works and sewerage matters.

I had occasion in three instances to use them before the maps were issued. In these cases I sent an assistant to the office of the geological survey where every facility was given him to trace copies from the office

maps, the scale of which is double that of the published copy. One of these I used in making my preliminary plans for the water-works system for Reading. Selecting the location of the standpipe on one of two hills which were clearly shown upon it; taking the westerly one on account of its superior elevation. Later on by my own levels I found that the easterly one was higher, and that one entire contour had been lost on the easterly hill.

This compelled a change in my plans and somewhat shook my confidence in the map. This however was restored soon after by finding it farther north where it had been sandwiched between two others at a lower elevation. Of course I was gratified to know that nothing had been lost.

In another case where I was making some approximate surveys for a similar purpose as that of Mr. Stearns, where an error of a few feet would not be of much account any way, I laid out a flow line around an abandoned mill pond in accordance with the map contours. A short time after I set up a level there and run in the same flow line on the ground, and found that the last one ran directly across the contour which was shown upon the map.

The third sheet which I used was in the Berkshire hills, but I have as yet had no occasion to test its accuracy.

I agree with the opinion of Prof. Chaplin that it would have been far better if the appropriation had been used as far as it would go in doing accurate work, and trust to future ones to make a map which could be to some extent at least of use and a credit to the Commonwealth.

I must confess that I was surprised at the inaccuracies which I found in that portion which I had occasion to put to test, and intended to make some comments upon them, but after listening to Mr. Cutter's statement of the manner in which the work was done I have nothing more to say.

Remarks by Prof. N. S. Shaler.

At the annual dinner of the Boston Society of Civil Engineers, March 10, 1891, Prof. N. S. Shaler, of the State Topographical Survey Commission, spoke of the new map of the State of Massachusetts, saying that his first interest and appreciation of the great value of good topographical maps, came during the war, and that "Stonewall" Jackson's success was due largely, to the excellent maps prepared for him at short notice by Jedd Hotchkiss whose power as a swift topographer has perhaps never been excelled.

In 1870 Prof. Shaler approached a number of members of the Massachusetts Legislature in the effort to induce them to undertake the preparation of a worthy map of this Commonwealth, and basing his estimates on coast survey maps, it appeared that an appropriation at the rate of about $70 per square mile would be needed to do the work in a really first class and enduring manner. He received no encouragement or sympathy in his labors, and the matter rested for awhile. On going abroad a few years later he studied the systems of map making followed by several of the European governments, and finally made up his mind that it was impossible to get the State of Massachusetts to appropriate sufficient money

for this work to enable it to be done in a thoroughly satisfactory manner. But in 1883, while assisting Major J. W. Powell, Director of the United States Geological Survey in some other matters, it was learned that he proposed to make an outline or sketch map of Massachusetts, compiling it in part from the older maps, with a view to using it as a ground-work for displaying the geological features of the State.

Interest in a State map was once more aroused, and a number of citizens thought perhaps here was an opportunity through co-operation with the federal authorities to get something, which though less perfect than desired, would at least be a great step in advance. As the result of again agitating the matter, the Legislature granted an appropriation and appointed a Commission, which served entirely without pay. This Commission worked from 1884 to 1889, and their only recompense except a few passes given by some of our railroads, was their satisfaction in helping along the good cause.

Under their supervision, parties were put in the field, and taking triangulation of the U. S. Coast & Geodetic Survey and that of the old "Borden Survey" as a ground-work, the topography was sketched in as well as the limited appropriation available, would admit.

The results of this survey have just been published and the map is now being issued by the State.

Prof. Shaler urged the engineers to keep in mind that this present map was a temporary rather than a final chart; that it was constructed at an average cost to the Commonwealth of only $5 per square mile, and should be relied on for suggestions rather than consulted as a basis for actual location either in railroad work or sanitary project.

For all popular purposes, it is practically sufficient but in its present form it is much less accurate and complete than the field sheet which according to the terms of the agreement with the general government are to remain in possession of the State.

This map as published is merely a transcription of these sheets prepared in Washington, and for purely geological purposes. The sheets belonging to the State contain in addition thereto the forest outlines and also the location of buildings.

Since this map has been somewhat criticised by parties who have mistaken views as to the precision which it is possible to secure in a work of this grade it is but fair to state that a large part of the existing errors are due to the engravers rather than to the surveyors. Every one of these maps issued by the state is marked as "temporary" and "subject to revision;" but notwithstanding all the little errors which have crept into it, it stands to-day the best map ever published by any one of our Commonwealths and is not far below some of the famous European maps in its standard of completeness.

This commission has still in progress the town boundary surveys which are now being carried on with an accuracy fully equal to the high standard of coast survey work, and frequent points are being located, (about one to every square mile throughout the state) with the utmost precision and marked by enduring monuments for future reference.

It will take some five to seven years to complete this careful geodetic survey, and when this is done we shall have the ground-work for one of the best topographical maps ever made, and some time before the present decade the prospect is hopeful that we may be able to undertake and gradually to publish another map on the scale of 6 in. to the mile, which shall show all these features of the configuration of the surface of the ground throughout the Commonwealth, with a high degree of accuracy and which may for many years endure as a standard.

TOWN BOUNDARY SURVEY OF MASSACHUSETTS.

By C. H. Van Orden, C. E.

[Read before the Boston Society of Engineers, May 20. 1891.]

I have been asked by your committee to read a paper on the Town Boundary Survey of Massachusetts, now being done under the direction of the State Topographical Survey Commission. This Commission, as you are aware, consists of General Francis A. Walker of the Institute of Technology, Chairman; Prof. Henry L. Whiting, Assistant Coast and Geodetic Survey, Secretary, and Prof. N. S. Shaler of Harvard College. As a matter of history the town boundary survey is an outgrowth of the topographical survey. It was found that the town bounds while being generally well marked, were often badly determined, the positions of the monuments uncertrin to hundreds of feet, and the records still more uncertain, in some cases none at all existing. These glaring faults being brought to the notice of the Commissioners, they were impressed with the importance of something being done in the matter.

The Commission therefore submitted the recommendation to the Governor that the latitude and longitude of the monuments at the corners and angles in the town lines should be determined, by connecting them by triangulation with the old points in the Coast and Borden surveys. This led to an act of the Legislature that authorized the work being done.

In 1885 I was detailed by the Superintendent of the Coast Survey to assist in this work; in 1886 I was placed on other duty; but in 1887 I was re-assigned to the work; from which time until the present I have been constantly employed. I beg your pardon for this long introduction.

The work is as follows:

First the perambulations of the towns are obtained from the respective selectmen and one or more of them has generally accompanied the parties to show and indentify the corners, then a general reconnaissance of the country is made; and only such as they say are the right ones and are at the true corners and angles in the lines are determined. When the corner can be reached directly by triangulation a signal is carefully placed over it, making it a point in a triangle and almost always common to two for check. When practicable all the angles of the triangles are

measured. When the corner is not to be seen from the old triangulation points the two are connected with our own triangulation, giving a double determination of each point when possible; this check (double determination) is not omitted except in rare cases—where the identity is beyond possibility of mistake or where all three angles can be measured and the triangle filled. In a well shaped triangle this check is nearly perfect. Concluded angles if they are between 60 and 120 degrees and are the supplement of well measured angles, give practically as good results as measured ones. When it is impossible to see a signal over a corner, a point as near it as possible is made—to which it is connected by means of a short traverse or steel tape base and triangle. A broken traverse with carefully measured angles and leveled tape is often used to avoid obstructions and rough ground. The traverse is straightened by the usual rectangular co-ordinate formula, where the origin of the co-ordinate is the triangulation point and the algebraic sum of the abscissæ and ordinates are the base and perpendicular of a right angled triangle whose hypothenuse is the straightened traverse; should there be but one angle in the traverse then two sides and included angle may be used, unless the angle is nearly 180 degrees, when, I think, it should be treated as a broken base where supplement of included angle is used. (Fig. 1.)

Where φ = supplement of included angle: a and b = the measured distances and c the required distance: then

$$\Sigma = \frac{\sin^2 1'}{2} \times \frac{a\ b\ \varphi^2}{a+b} \text{ and } c = a + b - \Sigma.$$

Care is taken to make the traverse as short as possible, often not exing 100 feet. Occasionally it is necessary to use longer ones, and where such have been checked they have proved satisfactory.

In this work the church spires have been of great service. There is scarcely a prominent one, within the limits of the work executed, that has not been determined. The belfry was almost always the place occupied, thus elevating the instrument from 30 to 70 feet. The signals which have done us the greatest good have been poles (generally cedar or white birch) cut in the woods and spliced together and put in a tree near the corner; they were sent aloft with block and fall and at each splice and under the lower flag sets (three each) of heavy wire guys are made fast. Immediately under the lower flag at upper guy, a space in the pole is wound with narrow bands of black and white cotton cloth as the point to observe on; and brought directly over the corner or station on the ground; the lower guys being hauled taut only to keep the pole from swaying, and changing the position of the observing point. Thus signals have been obtained that were often 100 feet high; and showing above the surrounding forest. By using these tall poles a tree could be used some distance from the point on the ground and the point observed on hauled over it by these guys. The difference in cost between this kind of a signal and a tripod of equal height is very great, the material for the former costing say $1.25, while a 75 foot tripod would cost from $10 to $15 not counting the hauling, the clearing trees away and greater labor in construction.

If a corner falls on a hill tall signals are, of course, not generally necessary.

As I have already said, when the signal could not be centered over a corner, a place near it was selected, care being taken that a geographical point be in sight—not necessarily one from which this position is made so as to obtain an azimuth for the direction of the traverse to the corner.

Still another kind of signal, with which I think the town boundary should be credited, is the use of the stand pipe or iron reservoirs of the numerous water works. These, as you know, are generally round and average about 25 feet in diameter and 100 feet in height, with a well defined flange and flat top—when not, as occasionally it is, carried up to a finial.

In observing upon these (the flat topped ones) by making one-half of the pointings of the angles on one side and the other half on the other, a nearly perfect center is obtained, thus in an angle of six pointings the first is made on the left and the next on the right, and so on, treating the

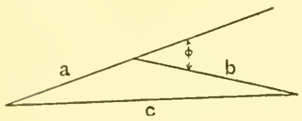

FIG. 1.

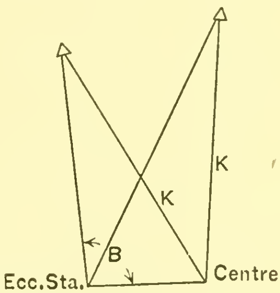

FIG. 2.

sixth pointings as though all had been made on the same point. In making these pointings a place immediately under the flange is selected so that all the pointings may be on the same place, for occasionally the structures lean, as in the case of the one on Sprague's Hill, in Bridgewater, at which place some of the best results were obtained. They are occupied with eccentric stations, either on the rim on top or the ground and the elements for reduction to center obtained with base and angles. The latter measured in before-described method, care being taken that the angle at the center with the base ends should be about 90 degrees. The corrs. for reduction to center may be found thus: (Fig. 2.)

$$\text{Corr.} = \frac{d \sin B}{k \sin 1''}$$

where d = eccentric distance, B = eccentric angle and k the distance centre to distant object. Correction is plus when a line drawn at eccentric point, parallel to k falls outside the measured angle, otherwise it is minus.

So far these large objects have given results equal to the ordinary signal. As they are always on the highest ground it is generally necessary to use them or build an ordinary signal where, especially if the hill-top be

small, a reservoir is very much in the way, its great diameter covering a large piece of horizon. They have proved of great service because of their elevated position, and the certain identity and ease with which they are observed in faint seeing. Of course, large, round chimneys can also be used this way; theoretically the object must be round, but a square structure is practically as good when the observer is distant 600 times its diameter. In fact any regular polygon with even number of sides is practically all right if the observer be at a reasonable distance. In a moment's thought you will see that in a triangle, pentagon, heptagon and the like this method of observing will not give the center until the number of sides of such polygons are so great that the figure becomes practically a circle.

My first experiment with this kind of a signal was the Standish Monument in Duxbury, and the results were so surprising that I decided to experiment further, and very soon discovered their great usefulness.

Where the important triangulation points are not natural objects, spires, cupolas, water-works, etc., they are marked for further use; those falling on rock with drill holes. Where they fall on the ground they are usually marked with an inverted flower pot three feet below the surface, over which is placed a 5″x 5″x 30″ stone post. In filling the hole the broken flower pot saucer and pieces of stone are scattered through the earth as a "scent" in case the monument has been removed and the sub-surface mark to be recovered. The center is a ¼ in. hole in top of post and the hole in bottom of flower pot; the monument is buried nearly flush with the surface. All the corners and permanent triangulation points have topographical sketches and descriptions of them carefully made.

In addition to this it is contemplated and partially executed to carry a line of levels along the principal railroads and at every important station, placing a copper plate bench mark on which will be stamped its height above mean sea-levol. So far a double checked line has been run from Orleans (Old Colony Railroad, Cape Cod Division) to Matfield, a distance of 70 miles. These levels have been connected with the tide gauge bench marks of Cape Cod and Buzzards Bays. The former is at the head of Cape Cod Bay about north of Sagamore, and the latter in Back River Harbor about one mile southwesterly from Buzzards Bay Station; at both of these places the mean sea-level has been determined by a long series of tidal observations and then referred to permanent bench marks. As the mean sea-level (though one has more than twice the tide the other has) is practically the same height at both; one was enough to connect with but both were run to with double lines for check and with satisfactory results. The copper bench marks have been placed as far as Bridgewater. The heights have been put on as far as Buzzards Bay; the rest are not to be stamped until the Boston Bench is reached. The plates for Buzzards Bay to Boston will then be the mean of the three benches.

Both position and direction instruments are used in the triangulation. The observations are made and the records kept in the method of the Coast Survey, as are also the computations. The triangles are treated as plain trial angles and computed by the usual sine formula, except when

their area exceeds 75 square miles when a small spherical excess becomes apparent. The position of the point is determined by the L. M. Z. formula; the latitude and longitude of each corner is computed. The corners are numbered beginning with the extreme southerly stone and increasing, as the azimuth, by the way of the west around the entire town, giving each town its complete number and recorded thus. "Boston corner (1) Boston corner (2) etc.

The work is to be issued in Atlas form. First giving a map of the town, generally on a $^1/_{30000}$ scale, on which is plotted the corners and boundary lines, and principal triangulation points; then comes the geographical position of the corners with the direct and reverse azimuth between adjacent corners and the true bearing and distance in feet and meters; then the positions and azimuths of the triangulation points; then follows topographical sketch of each corner and its immediate surroundings; a picture of the monument and a careful description, thus furnishing the town with a complete record of its bounds. Besides the direction given from corner to corner a direction and distance from any monument in any town to any monument in any other town can be computed, the direction turned off, the line traversed and the monument hit; thus saving, it seems to me, much time and expense in preliminary surveys in laying out streets, pipe lines, railroads and many other improvements. This, and the fact that the State will be covered with a mass of geographical positions adapted to all kinds of local or general surveys and more evenly distributed than by any ordinary triangulation would justify the expense of the survey, but if you will bear with me a moment while I point out a very few of the glaring mistakes and faults incident to the needle (that bane of good work) and generally imperfect methods of the old surveys, the necessity of the redetermination of all the town bounds will be very apparent. To us, who have been in the field, this necessity has been constantly before us. In the very beginning of the work we are brought face to face with very imperfect records and perambulations—not only uncertain but often misleading. It is not an uncommon thing to find the perambulations of adjoining towns differing widely. For example in the line between Brewster and Harwich; one town has a certain number of corners and in straight lines from stone to stone, while the other perambulation has one or two more monuments and follows the middle of the ponds, making a difference I should think of over 100 acres and considerable water privilege. In some there are no records whatever, only a memorandum of the line having been perambulated at such a time. In a great many neither course nor distance are given; in some the course only; in one case a decided bend of over 30 degrees and a distance of over ¼ of a mile is given in both perambulations, but as none of the old maps showed it and it seemed such an unnecessary bend one of the towns investigated it for us, and found, though it had been incorporated in the regular perambulations for years, that the line had never been other than a straight line. Another line over 3½ miles in length I was assured by the engineer, who ran it twice, was "perfectly straight," and that all the line and road stones were in line. I thought it a good chance

to test the accuracy of what seemed to be the best of needle work, and found the monuments from 8 to 109 feet out of line. When we consider the enormous diurnal swing of the needle and annual change as well as the local attraction, we are not surprised at the almost worthless results obtained. Another line of between 3 and 4 miles was run with a compass and the surveyor picked up a three town corner monument and moved it 180 feet southwesterly to where his line hit.

I have here Braintree, as determined by triangulation, plotted from the perambulations, the old map of Braintree, and Braintree from the adjoining maps, all on the same scale. The length of the sides differ from 100 feet to 1,200 feet, and the area from 400 acres to 750 acres. This needs no comment other than this: Where two surveys of a tract no larger than Braintree differs nearly a square mile, one or both of them are worthless. Braintree was selected at random and I do not think it worse than others. A vast number of monuments and bends have crept into the perambulations which do not belong there; many of them are property marks supposed to be in the town lines and in some way the needle bearings of the farm divisions have been incorporated into the perambulations and so have developed small bends. No doubt many of the crooked lines were originally straight. I determined one corner that both of the perambulations gave as a monument in the town line. When I had, at no small difficulty finished it, a gentleman told me it was a mark he himself had put there, and that it had no right in the records. I am tiring you with these axamples, but I could cover pages with the like data that have come under my observation. Occasionally the Selectmen of adjoining towns will differ as to whether a certain monument be the corner or not; the following will be nearly, if not quite, the degree of accuracy with which the work is done.

Let M represent the mean error of an adjusted or resulting angle. In the adjusted secondary Coast Survey work of Massachusetts, $M = \pm 3.7''$ and unadjusted $\pm 3.9''$. In the Borden survey it is found to be $6.0''$ and $6.4''$. It is hoped the main scheme of this work is nearly equal to the secondary just mentioned. It may be roughly expressed in terms of distance. The average error of the main scheme may range between $^1/_{40000}$ and $^1/_{20000}$ of the length, while that of the tertiary—the small triangulation reaching the difficult corners—may be estimated as low as $^1/_{10000}$ or less near its inferior limit. It has been a very difficult thing to decide just when the work was sufficiently well done, for in the determination of so vast a number of points (over 1,200, so far) economy becomes a serious element.

I cannot close without paying a tribute to the Commissioners unbounded personal kindness, doing everything in their power to help me. Mr. James B. Tolley has been my assistant during the entire time, to whose skill and industry a great deal of the success of the work is due; and for two seasons Mr. E. E. Pierce has been my assistant, to whom I am likewise indebted for a large amount of valuable work. If this feeble effort will help in directing surveyors' attention to the importance of improved methods and better work I shall feel my labor has not been in vain.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

APRIL 15, 1891:—A regular meeting was held at the American House, Hanover street, Boston, at 19:45 o'clock, President Stearns in the chair. Fifty members and twenty-two visitors present.

The record of the last meeting was read and approved.

Messrs. Joseph P. Gray and Frederic M. Hersey were elected to membership.

The amendment to by-law 6, substituting the words "two hundred dollars" for the words "one hundred dollars" as the annual salary of the Secretary, was adopted by a unanimous vote.

In regard to recommendations of the Committee on Permanent Quarters contained in its report submitted at the annual meeting, on motion of Mr. Brooks it was voted to authorize the Committee to issue a circular to members inviting subscriptions to stock in the proposed corporation to own a building.

The Secretary reported the appointment of the following committees by the Board of Government:

On Highway Bridges, J. E. Cheney, D. H. Andrews, E. S. Shaw.

On Weights and Measures, C. H. Swan, A. E. Burton, L F. Cutter.

On the Library, F. W. Hodgdon, S. E. Tinkham, H. D. Woods, X. H. Goodnough, J. H. Stanwood.

On Excursions, F. O. Whitney, G. T. Sampson, Dwight Porter, A. H. French, F. P. Spalding.

The Secretary called attention to the Eads Monument Fund and to the opportunity presented at this meeting for members to place their names on the subscription list. On motion of Mr. Rice, the Secretary was requested to issue a call for subscriptions in the notices of the next meeting.

On motion of Mr. F. O. Whitney a vote of thanks was passed to the North Packing & Provision Co. for courtesies shown the members on the occasion of the visit to the works of the company this afternoon.

Mr. George A. Kimball read a paper describing very clearly the Refrigerating Process, Water Supply and Sewerage System recently constructed by him at Somerville, Mass. for the North Packing & Provision Co.

Mr. H. T. Buttolph, Assistant City Engineer, of Buffalo, was then introduced and spoke very fully of the experience of that city with stone and asphalt pavements.

The subject of Highway Legislation was then taken up for discussion. The Secretary read a short paper by Mr. Clemens Herschel, giving an account of the efforts made in this state in 1870, to pass laws for the improvement of its common roads. Mr. W. E. McClintock followed giving the details of the two highway bills now before the legislature and his views on what could be and should be done to improve our country roads. The discussion was continued by Messrs. Noyes, C. F. Allen, Manley, Adams and Albert H. Howland.

Adjourned. S. E. TINKHAM, Secretary.

MAY 20, 1891.—A regular meeting was held at the American House, Boston, at 19:40 o'clock. President Stearns in the chair. Fifty-one members and sixteen visitors present.

The record of the last meeting was read and approved.

The Secretary read the following communication from the Board of Government:

BOSTON, MASS., April 22, 1891.

To the Boston Society of Civil Engineers:

The Board of Government respectfully recommends that Messrs. James B. Francis and Samuel Nott be made honorary members of the Society.

Messrs. Francis and Nott are the only members of the Society now on the list of members who joined the Society at its organization, July 1848.

In 1874 when the Society was re-organizrd, Mr. Francis was the President and Mr. Nott the Secretary of the Society and it was largely through their efforts that a union of the Societies of 1848 and of 1874 was consummated. At that time they both elected to continue active members of the Society, the other members of the old Society being placed on the list of honorary members. They now signify a willingness to be put on the honorary list and the Government is very glad to unanimously recommend that they be transferred to that class.

(Signed) FREDERIC P. STEARNS,
JOHN R. FREEMAN,
W. E. MCCLINTOCK,
S. E. TINKHAM,
HENRY MANLEY,
FRANK W. HODGDON,
FRED. BROOKS,
GEO. F. SWAIN,
Board of Government.

After a short discussion in which Messrs. Tidd, Allen, Manley and FitzGerald took part, a ballot was taken and the President announced the unanimous election of James B. Francis and Samuel Nott to honorary membership.

Messrs. William E. Baker, James T. Boyd, Benjamin G. Buttolph, Heywood S. French, Percy N. Kenway, Lewis J. Johnson, Herbert F. Pierce, Franklin C. Prindle and Edward W. Shedd, were elected members of the Society.

Mr. Tidd gave notice of an amendment to Article II of the Constitution, by striking out at the end of the third paragraph the words "and shall not be entitled to vote" so that it shall read:

Honorary members shall be men of eminent scientific attainments whom the Society shall deem worthy of the distinction. They shall be subject to no fees, dues or assessments.

Mr. C. H. Van Orden read a paper on the Town Boundary Survey of Massachusetts.

Mr. L. M. Hastings read a short paper entitled "Some Problems in City Engineering."

Mr. Desmond FitzGerald spoke of some of the interesting questions in connection with the construction of Basin V of the Boston Water Works and the method used to determine its capacity.

After passing a vote of thanks to Mr. Van Orden for his interesting paper, the Society adjourned.

S. E. TINKHAM, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

MARCH 21, 1891.—The regular monthly meeting of the Society was held at 8p. m. at the office of Messrs. Sizer & Keerl, Helena, Mr. W. A. Haven was elected chairman. Members present, Messrs. Kelly, F. J. Smith, Hovey, McRae, Pearis & Keerl.

Minutes of previous meeting read and approved. Messrs. Smith and McRae were appointed tellers to canvass ballots on membership.

The death of Mr. Franklin E. Worcester being announced, the tellers were directed to drop his name from the ballot list.

The chair announced the following as having been elected to membership:—A. M. Ryan, Wm. L. Darling, Samuel Bundock, J. P. Bouscaren, Charles W. Goodale and Herbert P. Rolfe.

The committee on the Revision of 'the Constitution and By Laws submitted a draft of a Revised Constitution and By Laws Several changes were suggested by the meeting and it was referred back to the committee recommending their insertion.

The Secretary was authorized to have printed a list of members of the Society.

A letter was read from the President naming the following *Standing Committees* for the current year.

Committee on Topics:—John Herron, W. S. Kelley and W. A. Haven.

Committee on Library:—George O. Foss, J. S. Keerl and W. W. de Lacy.

Committee on National Public Works:—E. H. Beckler, George K. Reeder and George H. Robinson.

The President also named the following special committee to investigate and to consider the subject of the creation by the Legislature of Montana, of the office of *State Engineer*:—W. A. Haven, H. B. Davis and A. B. Knight.

A number of communications were read and ordered filed.

(Adjourned.) J. S. KEERL, Secretary.

APRIL 18, 1891.—The regular monthly meeting of the Society was held at 8:30 p. m., at the office of Messrs. Sizer & Keerl, Helena.

Mr. F. L. Sizer was elected chairman. Members present:—Messrs. Wheeler, Hovey, McRae and Keerl.

Minutes of previous meeting were read and approved.

The committee on Revision of the Constitution and By Laws reported and read the changes proposed at previous meeting and as embodied in their draft of the Revised Constitution and By Laws.

On motion carried, the committee was directed to have the Revised Constitution and By Laws printed and a copy sent to each member of the Society, with the request that it be carefully examined and that any suggestions or amendments proposed be sent to the Secretary at least one week before the next regular meeting.

A communication was read from the chairman of the Board of Managers of the Association of Engineering Societies, relative to the application of the "Technical Society of the Pacific Coast," to join the association, and was referred to the Society's member of the board for action.

(Adjourned.) J. S. KEERL, Secretary.

MAY 16, 1891.—The regular monthly meeting was held at 8 p. m., at the office of Messrs. Sizer & Keerl.

Mr. Geo. O. Foss was elected chairman. There were present, Messrs. McRae, Wheeler, Herron and Keerl.

Minutes of previous meeting were read and approved.

The special committee on the Revision of the Constitution and By Laws reported, that the draft of the Revision had been printed and forwarded to the members for their consideration and submitted a copy which was read section by section. Several amendments were made to the draft as presented and on motion, carried, the Secretary was instructed to have the Constitution and By Laws as approved by this meeting printed and forwarded to members for letter ballot.

The Secretary reported that Mr. W. L. Loveland had removed from the State and desired to retire from membership. As Mr. Loveland removed from the State immediately after being elected to membership, a motion prevailed that his dues be remitted.

(Adjourned.) J. S. KEERL, Secretary.

ENGINEERS' CLUB OF MINNEAPOLIS.

FEBRUARY 2ND, 1891.—First joint meeting of the Minneapolis and St. Paul Clubs at the Ryan Hotel, St. Paul. After partaking of an elegant dinner, the members adjourned to the Club room, and listened to a paper on the History of Minneapolis Sewerage, by Mr. Wm. D. Van Duzee, of Minneapolis.

Afterwards, Mr. Munster's (St. Paul) paper on "A more convenient expression of Gordon's Formulae to facilitate calculations" was discussed at length.

Adjourned. F. W. CAPPELEN, Secretary.

FEBRUARY 14TH, 1891.—A special meeting was called to discuss Finances, Association Journal matter and printing and met at City Hall, Minneapolis. Vice President, T. P. A. Howe, in the Chair.

The Association Journal matter was first considered. It was explained, that in the early days of the club, some forty (40) to fifty (50) subscriptions to the Journal had been taken, but owing to the neglect of members, this entire expense had to be carried by a few only and caused continually a financial embarrassment of the club.

The subscriptions had been discontinued and left to the members individually, the result being the other extreme that only five (5) subscriptions were taken. It was however, voted, that the matter remain subject to the individual members.

A committee was appointed to investigate cost of printing, constitution and By-Laws, the printed pamphlets having run out. An assessment of Five ($5.00) Dollars per member was ordered, to provide funds for current expenses.

William Fox was proposed as a new member, certified to by C. O. Huntress and F. W. Cappelen.

Adjourned. F. W. CAPPELEN, Secretary.

MARCH, 5TH, 1891.—Second joint meeting of the Minneapolis and St. Paul Clubs held at West Hotel, Minneapolis.

After a pleasant dinner in the Ladies' Ordinary, the meeting was opened in the Club Rooms, Prof. Pike, of Minneapolis, in the Chair.

Mr. Sanford, a member of the Old Society, was made a charter member of the present club. A Book Case was ordered bought. William Fox was elected a member.

The Committee on printing, reported that fifty (50) copies of the constitution had been found, and that there was no need of printing more. Report adopted and committee discharged.

Mr. Rundlett, of St. Paul, read a paper on "Brick." Mr. Rundlett stated that fifty to sixty million were manufactured in Minnesota; all common brick, no pressed brick being manufactured in Minnesota of any account, Wisconsin, Missouri and Illinois furnishing the bulk.

The quality of brick depends in the first place on the clay itself and secondly upon the manipulation of the clay. Frosty nights or a hot sun, both bad. A cold draft on bricks in kiln, may spoil an entire arch. Mr. Anderson, of Chicago, has the most perfect arrangement for manufacturing brick. From the excavating of the clay with steam shovels to the burning of the brick in fire proof cars in tunnel ovens oading moulds on one end of the train, and taking off the finished brick at the other end.

Discussion brought out the fact that Menominee (Wisconsin) brick disintegrate on account of bad grinding and manipulation of the clay.

Mr. Starkey, of St. Paul, has a patent artificial dry house,. using hot air and steam combined. The patent being on the manipulation of the hot air current. Only pure air is used, as combustion air will discolor the brick.

A first-class brick should stand seven thousand (7,000) pounds per square inch and not absorb over one tenth (1-10) in weight of water.

In regard to efflorescense of brick, Mr. Starkey stated, that after thoroughly cleaning the efflorescense off (La Salle brick) his private house and coating it twice with boiled oil, the brick remained perfect.

Adjourned F. W. CAPPELEN, Secretary.

APRIL 6TH, 1891.—Third joint meeting at the Ryan Hotel, St. Paul.

Mr. S. D. Mason, St. Paul, in the Chair.

Mr. Cappelen, of Minneapolis, read a paper on the "Late Suspension Bridge of Minneapolis."

Adjourned. F. W. CAPPELEN, Secretary.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

ANNUAL BANQUET.—The Eleventh Banquet of the Civil Engineers' Club of Cleveland was held at the Stillman on Tuesday evening, March 17th. One hundred and sixty-five members and guests were present, among the latter being many of the most prominent Civil and Mechanical Engineers of Ohio. The time from eight o'clock till nine-thirty was very pleasantly spent in an informal reception. The menu was then served after which Mr. W. H. Searles, the retiring President, called the meeting to order and in a very pleasant speech congratulated the Club on the success it had made of these annual gatherings when so many eminent engineers and scholars met and renewed old acquaintances and formed new ones. He then read a number of letters of regret from members of the Club and friends who were unable to be present, among whom were Col. John. M. Wilson, Sup't. of the U. S. Military Academy at West Point, Mr. Charles Paine of New York, Mr. J. F. Holloway of New York, former presidents of the Club, Rev. Dr. John W. Brown, Gustav Lindenthall and others. The speakers of the evening were Prof. C. S. Howe of Case School of Applied Science, Dr. Carl H. von Klein, Cady Staley, President of Case School of Applied Science, Mr. C P. Leland, Mr. S.T. Wellman, Mr. W. R. Warner. Mr. John Eisenmann, Mr. James Ritchie, Hon. T. E. Burton, Hon. L. A. Russell and Dr. H. F. Biggar. Mayor Gardner expected to be present and make a short speech but was unavoidably absent and his place was filled and speech delivered by Mr. W. M. Day. All the arrangements had been most carefully made by the Committee in every detail and every one was well pleased. At the close each member and guest present took with him the seating diagram and *steel menu card* as souvenirs of the pleasantest evening's entertainment ever given by The Civil Engineers' Club of Cleveland.

APRIL 14TH, 1891.—Club met at 8 o'clock in the Club Rooms, President Gobeille in the chair and twenty-eight members and two visitors present. The minutes of the last meeting were read and approved. The Executive Board recommended the election of Mr. Henry Martin Morrison to Active Membership, and Mr. John B. Weddell to Corresponding Membership. It also recommended that the Club be incorporated. Ballots were canvassed for the election of Mr. Frank Roy Lander. The tellers reported that forty-one ballots had been cast all in the affirmative.

A vote of thanks was extended to Messrs. Anderson and Barr, for their donation to the Library of a copy of "The Washington Bridge."

The committee on programme reported the following calendar for the ensuing year:

May 12th, Civil Engineering and Surveying.
June 9th, Mechanical Engineering.
July 14th, Hydraulic and Sanitary Engineering.
Aug. 11th, Marine and Steam Engineering.
Sept. 8th, Rail Road Engineering.
Oct. 13th, Electrical Engineering,
Nov. 10th, Applied Science.
Dec. 8th, Architecture.
Jan. 12th, Engineering and Surveying.
Feb. 9th, Mechanical Engineering.
March 8th, Annual Meeting.
April 12th, Hydraulic and Sanitary Engineering.

The Committee on Banquet made its final report which showed a slight excess

of receipts over expenditures, which was turned over to the Treasurer. The report was accepted and the committee discharged.

Mr. Warner for the Committee on Club Rooms reported that the committee is doing all that can be done at present.

Mr. Mordecai announced that he would present to the Club a crayon portrait of our former President, now deceased, Mr. Charles Latimer.

Mr. Mordecai moved that the Executive Board be instructed to incorporate the Club. This motion was seconded and after a brief discussion it was voted upon and carried. A motion to reconsider was made and carried. Motion was made to refer the matter to the Executive Board with instructions to propose and submit to the members a printed circular stating briefly the reasons why the Club should be incorporated. Motion was carried.

Prof. C. H. Benjamin then read the paper of the evening entitled, "The Education of the Mechanical Engineer" in which he recommended giving the young engineer a practical as well as a theoretical education, training the hand and the eye as well as the mind. This was followed by a discussion by Messrs. Warner, Wellman, Swasey, and others.

On motion adjourned. A. H. PORTER, Secretary

MAY 12TH, 1891.—Club met at 8 o'clock in the Club Rooms, President Gobeille in the chair, and twenty-one members and three visitors present.

The minutes of the last meeting were read and approved.

The Executive Board reported Mr. Utley Wedge for election to Active Membership. The President appointed Messrs. Warner and Palmer as tellers to canvas the ballots for new members.

The President read a letter from Mr. Mordecai, donating to the Club a crayon portrait of Mr. Charles Latimer, our former President now deceased. On motion a vote of thanks was extended to Mr. Mordecai and to the artist.

Motion was made and seconded that the Executive Board be instructed to incorporate the Club. After a discussion by Messrs. Warner, Ritchie, Roberts, Searles, Barber, and Eisenmann, as to the propriety and advantage of changing the name of the Club, the motion was put and carried. The tellers reported that thirty-one votes had been cast and that Mr. Weddell had been elected. The President appointed for this Club Mr. Wm. T. Blunt, as member of the Permanent Committee on International Congress and Engineering Headquarters, in connection with the World's Fair. He also appointed as local committee on the same, Messrs. Barber, Eisenmann, Rice, Warner, and Whitelaw.

Mr. Jas. Ritchie then read a paper entitled "Recent Advancement in Electrical Engineering." This was followed by a discussion by Messrs. Warner, Barber, Porter, Roberts and Palmer.

Mr. Raymond a visitor present gave some account of the large Electric Welding Plant now in process of construction at Johnstown, Pa.

On motion adjourned. A. H. PORTER, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

348TH MEETING, MAY 20, 1891.—The club met at 8:15 p. m. in the club rooms, President Burnet in the chair, and twenty-two members and one visitor present. The minutes of the 347th meeting were read and approved.

Messrs. B. E. Chollar and E. A. Herman were elected members.

Messrs. Arnold Kuhlo and George R. Mann were proposed for membership.

The resignation of Mr. N. W. Eayrs was announced. Prof. J. B. Johnson offered his resignation as librarian.

On motion these resignations were accepted.

Prof. Johnson offered as an amendment to the by-laws—Sec. 4, that all after the word club on the second line be stricken out.

Messrs. J. A. Ockerson and S. Bent Russell were nominated for vice president, and Mr. R. E. McMath was nominated for librarian.

Mr. Carl Gayler then read the paper of the evening on "Our Viaducts Across the Railroad Tracks."

Mr. Gayler described some of the difficulties encountered with the bridges and some of the accidents that had occurred.

In conclusion a number of suggestions were given as a result of the experience obtained with the bridges already erected.

Discussion followed by Messrs Nipher, Seddon, Burnet, Farnham, Ayer, Gayler, Johnson.

The paper for the next meeting, June 3d, on "The Problem of Mechanically Propelling Road Vehicles," by Dr. Wellington Adams, was announced.

Adjourned. ARTHUR THACHER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

282ND MEETING, JUNE 3, 1891.—The 282nd meeting of the Society was held at its rooms, Wednesday evening June 3, 1891, at 8 p. m. President L. E. Cooley in the chair and 25 members and visitors present.

The minutes of the previous meeting were approved.

The Secretary presented the following members elected by the Board of Directors:

Messrs. Geo. W. Dorr and Robt. W. Hunt.

The following applications were also filed. Otis E. Hovey, John P. Force Chas. Warren Maynard, Wm. A. Illsley, John McKinnon.

Mr. C. L. Strobel was elected to fill the vacancy in the membership of the General Committee of Engineering Societies, Columbian Exposition, for the Western Society of Engineers, caused by the resignation of Mr. D. J. Whittemore.

On call by the President for reports of Committees the following communication was read from Mr. Richard P. Morgan, chairman of committee on "The Chicago Railway Problem, etc."

CHICAGO, May 20, 1891,

MR. L. E. COOLEY,

President Western Society of Engineers.

DEAR SIR:—As it seems probable now that I shall be absent at the time of th next regular meeting of our Society, I enclose herewith a copy of a resolution adopted by this Committee at their meeting on the 18th inst.

I respectfully present it to the Society, as a report of progress, and ask for th Committee, its approval of the resolution by granting to them the additional tim suggested.

Very respectfully yours,

(Signed) RICH P. MORGAN, Chairman.

COPY OF RESOLUTION, ADOPTED MAY 18TH, 1891.

Whereas:—A large amount of varied and important information has been obtained by this Committee by personal examinations, in this and other cities, and b an extensive correspondence; and

Whereas:—There are serious complications and undecided questions relative t the plan of the Sanitary District of Chicago which bear importantly upon the problem submitted to this Committee; and

Whereas:—More time is required to study the mass of facts already before th Committee in order that it may bring forward a plan that will in a practical manne at least ameliorate existing conditions though it may not entirely solve the problen and

Whereas:—One member of this Committee will devote a portion of the summe to a careful examination of terminals in European cities and this Committee wi have the benefit of his research Therefore

Be it Resolved by this Committee that it will devote the next four (4) months a far as other engagements of its members will permit, to this important subject wit a view to presenting in September or October next, or as soon thereafter as pract cable, the report to the Society.

The communication was received and placed on file

The President followed with remarks on the several committees and stated th: the Board of Directors would urge all committees to have reports ready for the Fa meetings of the Society, and that said meetings of the Society could be very pro

erly devoted to acting upon these reports from the several useful committees which have been organized in the past year, ending with discussions. Some of them are of very great importance.

The Secretary referred to a matter in the report of the Board of Directors, recommending a general meeting of the Society, say in August or about the 1st of September. It had been discussed by the Board of Directors in the past two meetings, the idea being presented that it would be desirable to have such a meeting, by which all our members would have a good opportunity to see what developments have taken place in this Society in the last few years—more especially for the benefit of our non-resident members. This is in accordance with a custom that has fallen into disuse. The Society in its early days held such meetings some time in July, I believe, but I am not aware of any such meetings having been held for the last six or eight years. The matter is laid before you this evening for your consideration as to the desirability of holding such a meeting. The Chair will be glad to hear any expressions of opinions in regard thereto.

MR. CHANUTE:—I move that the meeting be held at such time as may be selected by the Board of Directors, and that the Board of Directors arrange the programme therefor. Seconded.

No remarks being offered, the motion was put to vote and carried.

PRESIDENT COOLEY:—I am aware of no other business before the Society except the regular discussions of the evening, unless some member has some subject which he may be inclined to bring to the attention of the Society. If so, now is the proper time.

MR. A. W. WRIGHT:—I have had occasion to note in the older editions of "Trautwine," a paragraph on rails, wherein he states that where rails are fastened securely together in lengths of a hundred yards and upward and fastened to the cross ties in the ordinary manner, no contraction and expansion takes place. I would like to ask whether any member of the Society has had any experience in that regard. I noticed a paper bearing on the subject was read in the Philadelphia Society which corroborated the above statement. I have forgotten just when the paper was read. The author stated that he found it to be true. It is an extremely important matter. The question of joints is a troublesome one upon steam railroads. It is far more troublesome relatively upon street railways because we can only get at a joint by taking up the pavement, which is expensive, and we cannot put the pavement back in so good shape. Following out the idea last spring I thought of welding rails together, and in fact I wrote to get information regarding a welding machine, but it was not at that time in practical operation. I would be glad to know if any of the members have any information on the subject. The paragraph also states, Mr. President, that the action has never been satisfactorily accounted for.

THE PRESIDENT:—Do any good reasons for it appeal to you? We have several railroad men here who ought to be familiar with the question of expansion and the phenomenon described by Mr. Wright. We would like to know Mr. Wright what reasons have been given for such a phenomenon.

MR. WRIGHT.—Trautwine states it as a fact never satisfactorily accounted for In taking note of the subject myself the only reason that I could imagine is that expansion is a known force, and the friction between the spikeheads and the rail is intense, it is an intense force to a certain degree. For instance I have had occasion to move rails with the spikes in, and the friction is very great. Now suppose that the spikes in ordinary ties have sufficient strength to prevent the lateral motion of the rail and the force exerts itself in connection, condensing the rail, until the force becomes so great, that it is greater than the friction from the spikeheads, there must be an action at the end of that length, although Mr. Trautwine did not say so. I remember some years ago reports of Baron Von Weber in his experiments on lateral strength of rails as fastened with spikes He experimented on German railroads by taking a Tee rail and then putting a lever to the head and the ordinary thickness of metal in same was not sufficient to pull the spikes. He then planed the rail and continued his experiments, and he found, as I remember the experiment, that one-eighth of an inch thickness in stem with leverage of 4¼ inches equalled the holding power of the spike. I made myself quite a large number of experiments some years

ago on the adhesion of spikes and it is very great. Where tracks spread the action takes place usually at the joint unless the ties are very rotten.

PRESIDENT COOLEY:—Have no actual experiments been made?

MR. WRIGHT:—My recollection is that such an experiment was made by a member of the Philadelphia Society and a paper read before that society, but I do not know the date

THE PRESIDENT:—Has any one any further remarks to make in regard to the question raised by Mr. Wright?

MR. CHANUTE:—If the rail was the old fashioned joint rail, I can say that I saw it laid in 1850 on the Hudson River R. R., miles and miles of it The rail was rolled in two halves, and they were riveted together but the rivet did not quite fill the hole. The rivet was round and there was a space allowed at the end of the half rail for expansion. As I remember it, that rail gave trouble. It was short lived and in six or eight years after it was laid, the joint rail was taken up on the Hudson River road and an ordinary rail was put in its place. There have been scores of rails tried at various times consisting of three pieces instead of two, but all have proved inferior.

PRESIDENT COOLEY:—I think it would be very appropriate to have this matter entered in the minutes, and we can have some further discussion on it. If there are no further special matters, we have an unfinished paper or an unfinished discussion of Mr. Corthell's paper on "An Enlarged Waterway between the Great Lakes and the Atlantic Seaboard." This paper of Mr. Corthell's is by no means intended to end the discussion. The directors of the Society, I think quite unanimously, would like to keep the matter open as very likely we may have other papers on the question. It is a point of very great importance to the West and to the country at large. in fact the suggestion has been made by some that expert men be asked to give their views upon it.

The discussion which was read by the Secretary will be published in the June issue of the JOURNAL.

PRESIDENT COOLEY:—If there is nothing to be said on this subject this evening, we have the promise of some remarks by Mr. John F. Wallace in regard to the Lake Front question which some of you may have heard about.

The paper read by Mr. Wallace called forth many remarks, and was illustrated by large maps. It is expected to publish it as complete as possible in an early issue of the JOURNAL.

At the close of the paper, President Cooley called attention to the question of adjournment and after some discussion it was moved and seconded to adjourn until the first regular meeting in September.

JOHN W. WESTON,
Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES

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THE CHEMICAL PRECIPITATION OF SEWAGE.

BY ALLEN HAZEN, S. B.

[Read before the Boston Society of Civil Engineers, June 17, 1891.]

The necessity of purifying sewage, to a greater or less extent, before turning it into streams or ponds, especially when the volume of sewage is large in comparison with that of the water into which it flows, has long been recognized. A very large number of people have worked upon this problem of sewage purification and have proposed methods of treatment. These methods can conveniently be divided into two classes,—those which separate the impurities, or a portion of them, with little or no change, and then deal with the separated impurities, and those which destroy the organic matters by oxidation without first separating them. In the first class come mechanical filtration and the various processes of chemical treatment, (for oxidation by chemicals has never proved successful), and also the Webster electrical process. In the second class are broad irrigation and intermittent filtration.

There has been a very general and strong belief, that, some one process of treatment was to solve the problem in all cases, and many books and pamphlets have been written to show that either broad irrigation, or some one process of chemical precipitation, was the best process, and should be adopted everywhere.

Careful study has led, however, to a different view of the subject, and we can no longer suppose that any one process will be everywhere successful. In deciding what process to adopt in particular cases, the local conditions, such as the character and amount of sewage, and the quality and price of land available for irrigation of filtration, the climate, etc., must be taken into consideration. Under the bright continental sun, with broad plains of sandy soil at their dispòsal, several large German cit-

ies have used their sewage for broad irrigation with a good degree of success. The same is true of Paris and many cities and towns of Southern England having a more or less similar climate and soil. But in Central England, with a compact or clayey soil, and with an atmosphere so dark that the sun only has an occasional chance to shine on Sunday, with sewage containing large quantities of chemicals injurious to plant life and with rivers so foul that no one thinks of keeping them pure enough for water supply,—under these conditions, the various chemical processes have been, and are, more popular than broad irrigation.

The investigations of the Lawrence Experiment Station have led us to believe that our climate, for the greater part of the year at least, is well adapted to irrigation or intermittent filtration, and that the difficulty with snow can be overcome, as indeed it has been done at Berlin and at Framingham, in this state. We also believe that we have at our disposal, here in New England, sand deposits which are even better adapted to the work of sewage purification than the fields now in use abroad, and it seems probable that, they will prove of great value in many or most cases where sewage purification is required.

While irrigation and intermittent filtration have unquestionably great advantages over chemical precipitation, where local conditions are favorable to their use, it seemed desirable to collect reliable information in regard to the most important of these chemical processes.

Of the sewage found in our city sewers, the inorganic portion consisting of sand and various salts, is, from a sanitary point of view, quite harmless. Another portion, the organic matter, furnishes abundant food for bacteria, always present in great numbers. To remove this organic portion is the great problem in purification.

If sewage is allowed to stand for a few hours, a portion of the organic matter will settle out; but the greater part is either too finely divided to separate in a moderate length of time, or is in solution. By adding certain chemicals to the sewage, an inorganic precipitate is formed, which settles rapidly, and carries with it nearly all of the suspended matter, and also a portion of the dissolved matters. This is the *chemical precipitation of sewage*. Nothing definite is known of the chemistry of the process which makes insoluble a portion of the dissolved organic matter, but it is probably similar to the use of mordants in dyeing for fixing soluble colors.

Chemical precipitation is practically carried out in tanks or settling basins 4 to 7 feet deep and of sufficient capacity to hold one-half of the daily dry weather flow of sewage. The sewage usually flows continuously into one end of a series of tanks after being mixed with the chemicals, and, flowing very slowly through the tanks, deposits the suspended matter, and finally flows over a weir at the lower end in a clarified condition. The tanks are drawn off in regular order from time to time, for the removal of the deposit or sludge, only one usually being empty at a time.

It has been claimed that this deposit would make a valuable manure;

but experience has not borne out the claim, for from 70 to 80 per cent. of the total fertilizing value of the sewage is in solution and incapable of economical precipitation. As a matter of fact, chemical precipitation works, instead of selling their sludge at a profitable price, have been forced to dispose of it in the cheapest way possible, the leading methods being transportation in ships to the deep sea, digging into land, and pressing and drying for use as a fertilizer, although even in this case, its value is so small that only a nominal price, if anything, is obtained. The engineering details of the construction of tanks, and of machinery for grinding and mixing chemicals, and for the treatment of sludge have been carefully worked out in many places and fully described. They are not within the scope of this work. We were mainly interested in finding the exact action of the different precipitants, and in determining the most suitable proportion of the various chemicals and their respective merits.

The chemical precipitation works abroad are often in the hands of private companies, interested in introducing the same processes elsewhere, and so it happens that their statement must be taken with some allowance. The official reports are good as far as they go, but are usually incomplete, dealing rather with the details of treatment found to be suited to particular circumstances, than with the principles of treatment which would, under varying conditions, render a process successful.

It was to obtain such information of a general character that, a series of experiments upon the chemical precipitation of sewage was made at the Lawrence Experiment Station.

The substances best adapted and most commonly used for chemical precipitation are lime, and the salts of aluminum and iron.

I have endeavored, in the following described experiments to determine, first, the best method of using each chemical, and to establish, if possible, some relation between the composition of the sewage and the amount of precipitant which will give the best result, or as good a result as a larger quantity; and, second, to compare the effect of equal values of the different precipitants upon the same sewage, after finding, by the first experiments, how to use each with the greatest advantage. The experiments also give an idea of the amount of matter which can be removed by chemical precipitation under favorable circumstances. The observations have been confined to the composition of the sewage and of the effluent, neglecting the sludge altogether.

Methods Employed.

The first experiments were made in a tank holding about 700 gallons. As the sewage came by gravity through a trough, chemicals in solution were allowed to run in, and to become thoroughly mixed with it. The sewage then ran from the trough to the tank, where it was allowed to settle. A portion of the sewage was diverted into a smaller tank, before mixing with chemicals, and allowed to settle for the same length of time, for comparison.

While this method of precipitation in a large tank approaches in many ways more closely than any other to a sewage plant on a large scale, it did not prove satisfactory for the end that we had in view, *i. e.*, comparative results with the same sample of sewage. Since the composition of sewage is constantly changing, there was not only a great difference between the sewage of different days, but also between the different portions of sewage required to fill the same tank. It was thus impossible to compare strictly the effluent with the original sewage; for the chlorine shows that in almost every case the sample of sewage taken for analysis does not represent exactly the same sewage that the effluent does. Moreover, it is evidently unfair to compare the effect of different chemicals upon different sewages, unless, indeed, the average of a large number of experiments upon similar sewages, by each process, is taken. To work out in this way the problems which it was hoped to solve, seemed almost impossible.

It was decided that the only way to get entirely satisfactory results was to make several parallel experiments on the same sample of sewage. To accomplish this, barrels were set so that they could be filled from one of the sewage tanks. The tank was filled with sewage and thoroughly mixed, and, while it was still being stirred, the barrels were filled from it and chemicals added as desired. One barrel was left to settle without chemicals, for comparison. It is possible, in this way, to get several comparable results. The barrels were 30 inches high, and held about 50 gallons each. As the capacity of each was accurately known, it was easy to compute the amount of precipitant for each barrel, at any desired amount per 1,000,000 gallons. The sewage in each barrel was thoroughly mixed with the chemicals, and allowed to settle. A sample of the effluent above the sludge was then drawn from a tap about 10 inches from the bottom, first letting it run freely for a minute, so that the sample fairly represented the contents of barrel, above the very thin layer of sludge. The time of settling has been uniformly one hour. A slightly better result would be obtained by waiting longer before taking the samples; but a few experiments have indicated that the difference between one and four hours' settling is very slight, and, in comparative experiments, the advantage of making the experiments and completing the chemical analyses on the same day (thus avoiding change by putrefaction) is very great. It is also thought that an hours' settling in a tank thirty inches deep may be equivalent to two or three hours' settling in a tank six feet deep.

The organic matter of sewage is in a state of rapid change, and very different results for loss on ignition and albuminoid ammonia will be obtained from the same sample, if it be examined at different intervals of time after collection. The addition of the chemicals used for precipitation removes in many cases a large portion to the bacteria, and in these cases the decomposition goes on much more slowly than in the untreated sewage. In order to ascertain the amount of organic matter removed, it is necessary in all cases to determine the ammonias and to evaporate for the solids immediately after taking the sample. In all the following experiments these determinations have been so made.

Turbidity has been determined by noting the depth in the barrel at which a small platinum wire can be seen. The number given is one divided by the depth in inches. Thus, when the wire can be seen four inches, the turbidity is 0.25. The result depends to some extent upon the light, and the experience of the observer, but the comparative results are very satisfactory.

The alkalinity is obtained by titrating 50 cubic centimeters of sewage with twentieth normal sulphuric acid, using methyl orange as indicator, and the result is expressed in terms of normal acid per 100 cubic centimeters. The "acid number" is obtained by titration with acid, using phenolphthalein as indicator, and is given in the same terms as the alkalinity. Sewage and effluents, from precipitation without lime, or with a small amount of lime, do not color phenolphthalein. In this case, an excess of standard lime water is added, and the excess titrated with acid. The amount of normal acid equivalent to the lime required per 100 cubic centimeters is given as the acid number with a negative sign.

The bacterial examinations have been made under the direction of Professor Sedgwick at the Institute of Technology in Boston.

Precipitation with Lime.

The quicklime of commerce does not have a constant composition. It has been thought best, for the purpose of these experiments, to take an arbitrary amount of calcium oxide in solution as lime water, to represent a ton of lime, rather than weigh out lime for each experiment. This method will give strictly comparable results, while, if the lime was weighed out, there would always be uncertainty as to the composition of the portion used, as different lumps of lime from the same barrel, and even different portions of the same lump, may differ widely from each other in composition. Quicklime only contains, on an average, perhaps 80 to 85 per cent of uncombined calcium oxide, and a portion of this is difficultly soluble, so that it is impossible to make a lime water which represents the full theoretical strength of the lime. In a few experiments in dissolving lime in sewage, 10 to 15 per cent of the lime proved to be not easily soluble. From these experiments I have assumed that lime will, on the average, yield 70 per cent of its weight of calcium oxide in solution. This is believed to be a fair estimate, which can be obtained in practice, and I have taken it as a basis for computing the amount of lime used in each experiment. The lime is slaked with a large amount of sewage, and, after settling, the acid number is obtained by titration. From this is calculated the amount of lime water to be added to the sewage.

By treating sewage with a large excess of milk of lime, the undissolved calcium hydrate, in settling, carries down the insoluble organic matter almost completely, and in a very short time.

An experiment was made as follows: A weighed portion of lime was slaked in a barrel, and the barrel filled with sewage. After settling for a few minutes, the cleared liquid was drawn off, and the barrel again filled

with sewage. This was repeated until the lime was exhausted. In all 480 gallons of sewage were treated. The lime used was at the rate of 6,600 pounds per 1,000,000 gallons; 4.8 gallons of sludge were left having 4 per cent of solid matter.

The greater part of the organic matter was removed, and the bacteria were reduced from two million to twelve, which is practically a sterilization considering the number present at the start. This process could not be used on a large scale, owing to the amount of lime required, and the excess of lime left in solution, which would slowly precipitate out on exposure to the air. The completeness with which the bacteria are removed, or killed, and the large volume of liquid which can be treated in a small tank, might render it of use in some cases for disinfection.

The action of smaller amounts of lime is quite different. Calcium carbonate is then formed with the carbonic acid of the sewage, and it is thus the carbonate instead of the hydrate which clarifies the sewage. Calcium carbonate is somewhat soluble in water or sewage containing carbonic acid, and to obtain a precipitate, it is necessary to add enough lime to combine with the greater part of the carbonic acid.

The amount of calcium carbonate precipitated in any experiment can be computed in three ways:—

First, from the alkalinity. If we add the alkalinity of the sewage to that of the lime used, we obtain the total alkalinity of the mixture. As calcium carbonate precipitates, the alkalinity becomes less, and the decrease multiplied by 50, the equivalent weight of calcium carbonate, gives the amount of the precipitate.

Second, from the solids. One ton of lime per million gallons is equal to 30 parts per 100,000 calcium carbonate. If we add the weight of the lime used to the fixed residue of the filtered sewage, and deduct the fixed residue of the precipitated sewage, we shall obtain the amount of the precipitate.

Third, from the carbonic acid. The difference between the acid number with phenolphthalein and the alkalinity represents one-half of the total carbonic acid, and the decrease in carbonic acid represents the calcium carbonate precipitated.

These processes usually give fairly concordant results, and the average of the three has been used. The different methods are quite independent of each other, and the possible sources of error are entirely different.

The first and second are affected by the accuracy of the measurements of the sewage and lime, while the third is entirely independent of those measurements.

Four series of experiments were made with different amounts of lime. In each case seven barrels were filled from the same mixed tank of sewage, and different amounts of lime added, making a regular series, every barrel having more lime than the next below. These series were plotted and studied in detail. The results with the diagram are given in the second volume of the Massachusetts State Board of Health report on water supply and sewage. Only the conclusions are here given. Up to half a

ton of lime very little calcium carbonate is precipitated. It is held in solution by the excess of carbonic acid. From this point it increases rapidly as far as the experiments were carried. The amount which might be precipitated by increased amounts of lime is limited by the amount of carbonic acid present, and for the sewages used could not exceed 35 to 40 parts per 100,000. It was found that the maximum precipitation of calcium carbonate is not reached when the lime is equal to the carbonic acid. for, even without free carbonic acid, the sewage holds in solution a very considerable quantity of lime.

With quantities of lime too small to cause precipitation of calcium carbonate the result is little better than that obtained by settling sewage without chemicals. With larger quantities of lime, and increasing precipitation of calcium carbonate, there is a regular improvement in the effluent until the point is reached where the lime is equal to the carbonic acid. The addition of a larger amount of lime than this does not usually remove more organic matter, and, indeed, the effluent frequently contains somewhat more impurity than with a smaller quantity. This may be due to the solvent action of caustic lime, which is only present when the lime is in excess. An increase of lime does, however, kill the bacteria, the effluent being practically sterile when a very large quantity is used.

It thus appears advantageous to use an amount of lime which exactly suffices to form normal carbonates with all the carbonic acid presents. The quantity required can be calculated from the composition of the sewage. The analysis necessary for this purpose is of the simplest character, requiring only a few minutes. The difference between the acid number with phenolphthalein and the alkalinity represents the carbonic acid as a mono-basic acid, and twice this, its equivalent as a di-basic acid. Base equivalent to this must be present to form normal carbonate. An amount of base shown by the alkalinity is already present, and we have, for the amount of lime to be added, the equivalent of the alkalinity less twice the acid number with phenolphthalein. It follows from this, that at the neutral point the alkalinity will be just twice as great as the acid number with phenolphthalein. The great ease and accuracy with which these determinations can be made enables one to determine at any point the amount of lime to be added, or the excess. This determination is not affected by precipitation of calcium carbonate, for in that case the acid number with phenolphthalein is decreased just one-half as much as the alkalinity. The results obtained by this caleulation agree well with those obtained by trial. Thus, on October 9, the calculated amount was 1,633 pounds. By trial 1,600 pounds was found to be too little, and 1,800 pounds too much.

Precipitation with Copperas.

Copperas, or ferrous sulphate, occurs in commerce in a nearly pure form. Its value for the treatment of sewage depends upon the precipitation of ferrous hydrate or carbonate. Preliminary trials indicated that it is

necessary to add lime with copperas, in order to get the best result. Experiments were made to ascertain how much lime is required, and the effect of different amounts of copperas, and whether the sewage should be first mixed with the lime or the copperas.

Seven barrels were filled with sewage from the same large tank. To the first was added a certain amount of copperas, and to the other barrels, the same amount of copperas and different amounts of lime forming a regular series as with lime alone. In other series different amounts of copperas were used.

It was found that, when copperas is added to sewage alone, no precipitation takes place, and the result is no better than when sewage settles alone. The addition of enough lime to combine with the excess of carbonic acid over the amount required to form bi-carbonates, and to combine with the sulphuric acid of the copperas, is necessary for precipitation; for, while sewage is alkaline, its alkali is all in the form of bi-carbonate, and alkali as normal carbonate or hydrate is required to precipitate the iron. When this amount is added, the acid number with phenolphthalein will be zero. To insure a rapid action, a little more than this should be added. The amount of lime may be calculated from the analysis, and the calculation agrees well with the amount found by trial. No better result is obtained when more lime is used. If much less is used, the iron will not be precipitated, and the result will be the same as if the sewage had been settled without chemicals.

The test with phenolphthalein shows instantly whether enough lime has been added, and it can be used by any one. It consists of adding a few drops of a solution of phenolphthalein in alcohol to a portion of sewage in a small dish. If enough lime is present, it will be turned blood red, while, if enough lime is not present, it will remain uncolored. The smallest amount of lime which will give the reaction gives as satisfactory a result as a larger quantity.

This reaction is equally useful in the precipitation by lime of acid sewage containing iron from manufacturing waste. In this case, the copperas is carried by the sewage, and the addition of lime is required to neutralize the acid and precipitate the iron, thus rendering it available. For this reason the conditions of successful precipitation of such sewage, and the results obtained, correspond with the copperas treatment rather than with the lime treatment. But in case the sewage contains no iron in solution, the phenolphthalein reaction is given long before enough lime has been added, and for the best results, the quantity of lime must be regulated as has already been described.

It was found that, with increasing amounts of copperas, with the proper amounts of lime in each case, the effluent was regularly better, but nearly all the advantage was obtained with half a ton. One hundred pounds of copperas gave a result very slightly better than sewage settled alone.

In all of these experiments the sewage was first thoroughly mixed with the lime water, and then the copperas added. Experiments were made to see if a better result could be obtained by mixing the sewage with the

copperas first, and then adding the lime, or if as good a result could be obtained by precipitating the copperas with lime, and adding the precipitated ferrous hydrate to the sewage.

It was found that, with 500 pounds of copperas and an equivalent of lime, the best result was obtained when the sewage was first mixed with the lime, *i. e.*, in the way the preceding series had been made. With 1,000 pounds of copperas the difference between these two ways of mixing was insignificant. When the copperas was precipitated by lime before adding it to the sewage, the result was unsatisfactory, both when the amount of lime used was the same as in other experiments, and when only enough was used to combine with the sulphuric acid of the copperas. We may conclnde, then, that neither of these ways of mixing is more advantageous than that which was used for the preceding experiments.

Precipitation with Ferric Salts.

Ferric salts have the advantage over ferrous salts, in that ferric hydroxide is more readily precipitated, and more completely insoluble than ferrous hydroxide.

Experiments were made to determine whether it is necessary to add lime to obtain the best results with ferric salts, and, if so, how much should be used; and also to find the effect of different amounts of ferric oxide. The salt used for the experiments was ferric sulphate, but there is every reason to suppose that exactly the same results would be obtained with ferric chloride containing an equal amount of iron. The method of making these experiments in series, with regularly varying amounts of chemicals, was the same as that used for lime and copperas.

It was found that the influence of lime on the result is very small. With 200 pounds ferric oxide as sulphate, the result was slightly better when lime was used; but the difference does not compare with the increased cost. With 400 pounds of ferric oxide, the lime had almost no influence whatever. With 300 pounds ferric oxide, no better result was obtained by mixing the sewage with 1,000 pounds of lime before adding the ferric sulphate, and when the lime was added to the sewage after the ferric sulphate, the result was not quite so good as when no lime was used.

These results show that, while ferrous salts are only precipitated by normal carbonates or hydrates, ferric salts are also precipitated by bi-carbonates, and in the presence of free carbonic acid. For this reason, the reaction with phenolphthalein, which proved to be of so much importance in precipitation with copperas, is of no value with ferric salts, and the addition of lime to an ordinary alkaline sewage is quite useless. The experiments show that, as with copperas, the more of the precipitant used, the better is the result.

Precipitation with Aluminum Salts.

Aluminum sulphate, or crude alum, is now made for use in the dye-house, for decolorizing peaty water, and for sewage precipitation. Its ac-

tion upon sewage is analogous to the action of ferric sulphate. There is every reason to suppose that aluminum chloride containing the same amount of alumina would give exactly the same result as the sulphate. Experiments were made to determine whether lime could be used advantageously with alum, and to find the effect of different amounts of alum. It was found that, as with ferric sulphate, lime has little or no effect. With lime the precipitation is a little more rapid, but the short time gained by its use would hardly compensate for the extra cost.

The result with 1,000 pounds to the 1,000,000 gallons is, on the whole, somewhat better than with 500 pounds, but the difference is much less marked than with corresponding quantities of copperas or ferric sulphate.

Comparison of the Different Precipitants.

The foregoing experiments indicate that a certain definite amount of lime gives as good or a better result than either more or less; and that, in general, the more copperas, ferric sulphate or alum is used, the better the result; and that ferric sulphate and alum usually require no lime for complete precipitation, while with copperas a definite amount of lime must be used.

It now remains to compare the results obtained with the best amount of lime, and with equal value of the other chemicals, upon the same sample of sewage when used under the most favorable conditions. Two series of experiments were made in this way.

In calculating the cost of chemicals the price of lime containing 70 per cent. available calcium oxide is taken at $9. a ton; of copperas containing 26 per cent. ferrous oxide, $10. a ton; of crude alum containing 14 per cent. soluble alumina, $25. a ton. The cost of ferric sulphate is an estimate of the cost of manufacture, from copperas, nitrate of soda, and sulphuric acid. The approximate cost of these oxides in solution is as follows:—

Aluminum oxide	9 cents per pound.
Ferric oxide	3 cents per pound.
Ferrous oxide	2 cents per pound.
Calcium oxide	⅔ of a cent per pound.

It seems altogether probable, considerable the cheapness of the materials from which they are prepared, that the cost of both crude alum and ferric sulphate, or the corresponding chlorides, might be materially decreased from the prices given in case there should be a considerable demand for them.

One hundred gallons of sewage daily for each inhabitant is assumed in calculating the annual cost.

Of course the figures would have to be corrected for particular places, taking into account the price and composition of the lime used, and the amount and composition of the sewage.

The average results of these comparative experiments upon the same sewages are as follows:—

The Per Cent. of Soluble Organic Matter Removed by Chemicals of Equal Value.

Cost of Chemicals Used.	Thirty Cents.				Forty Cents.	
	Lime.	Copperas and Lime.	Ferric Sulphate.	Alum.	Ferric Sulphate.	Alum.
Soluble albuminoid ammonia removed.	22	29	32	20	41	29
Soluble loss on ignition removed.	4	21	28	30	45	20
Turpidity removed.	77	70	81	77	83	77
Bacteria removed.	93	38	92	91	93	93
Yeast removed.	92	98	95	82	95	90

To calculate the proportion of soluble matter removed, it is assumed that all the suspended matter is first removed, and that the rest must be soluble matter. This very nearly represents the truth, but a small amount of suspended matter is always left.

If we take the percentage of albuminoid ammonia removed to represent organic matter, we find that, in addition to all the suspended matter, the following amounts of soluble organic matter have been removed:—

Soluble Organic Matter Removed by Chemicals at Different Costs.

With lime costing 30 cents........per inhabitant annually		22 per cent.
With copperas and lime costing 30 cts.	"	29 per cent.
With ferric sulphate costing 30 cts....	"	32 per cent.
With aluminum sulphate costing 30 cts.	"	20 per cent.
With ferric sulphate costing 40 cts....	"	41 per cent.
With aluminum sulphate costing 40 cts	"	29 per cent.

The proportion of organic matter removed, as indicated by the loss on ignition, usually agrees fairly well with that obtained from the albuminoid ammonia; but the results are not regarded as so sure an indication of purification as is the albuminoid ammonia. By far the greatest difference was with lime, where 22 per cent of the soluble albuminoid ammonia was removed, and only 4 per cent of the soluble loss on ignition.

The removal of bacteria is due in part to the mechanical action of the precipitate carrying them down, and in part to the chemical action of the

precipitant in killing them. In the latter case, even if the bodies remain they are not counted, for dead bacteria do not affect the method of determination used.

The yeast, on the other hand, is a measure of the completeness with which exceedingly small insoluble bodies are removed from the sewage; for, even if killed, the dead yeast cells are nevertheless counted as well as the living ones by the microscope. It will be seen, from the few series where the yeast cells have been counted, that the yeast is never completely removed. This indicates, as does the turbidity, that a small amount of suspended matter is always left. This suspended matter consists largely of minute particles of the precipitate, which have either escaped the first rapid settling, or have only been precipitated after it. The particles are usually present in only small amounts, and when the effluent is so clear that a pin can be seen through a foot or more of it, as is the case in a successful experiment, they cannot be regarded as of any practical importance. The color of the effluent is, however, affected by them in a marked manner. When alum is used, the particles are white and almost invisible, while if copperas is used they are greenish, turning red on exposure to the air, and with ferric sulphate they are red from the first. These particles of ferric hydroxide, too small to be seen individually give the whole liquid a light red color.

It does not seem to me that the slight color given by the use of iron should be considered an objection in judging the merits of the different processes. It should be remembered that, when alum is used, a small portion of the alumina is really present in the effluent, but, being white, it is not noticed as is a corresponding amount of iron.

The lime process has little to recommend it. Owing to the large amount of lime water required, and the difficulty of accurately adjusting the lime to the sewage, very close supervision would be required to obtain a good result, and, even then, the result is inferior to that obtained in other ways.

Precipitation by copperas is also somewhat complicated, owing to the necessity of getting the right amount of lime mixed with the sewage before adding the copperas. When this is done, a good result is obtained. The amount of iron left in the effluent is much greater than with ferric sulphate, owing to the greater solubility of ferrous hydroxide.

Ferric sulphate and alum have the advantage over both lime and copperas, that their addition in concentrated solution can be easily controlled, and the success of the operation does not depend upon the accurate adjustment of lime or any chemical to the sewage.

The results with ferric sulphate have been, on the whole, more satisfactory than those with alum. This seems to be due in part to the greater rapidity with which precipitation takes place, and in part to the greater weight of the precipitate. It is probable, from the greater ease with which ferric sulphate is precipitated, that it would give a good result with sewage that was not sufficiently alkaline to precipitate alum at once.

It is quite probable that the same process would not give equally good

results upon all kinds of sewage. Special sewages may require special treatment. For this reason, and also on account of changes in the prices of the several chemicals, it is impossible to say that one precipitant is universally better than another.

PURITY OF EFFLUENT.

In the latter experiments, from 25 to 43 per cent. of the soluble organic matter, as shown by the albuminoid ammonia and loss on ignition, has been removed, by copperas, ferric sulphate or alum costing from 30 to 40 cents per inhabitant annually. In addition to this, all of the suspended matter is removed.

In the sewage used for the experiments, 41 per cent. of the organic matter, as shown by the albuminoid ammonia, was in suspension, while in the year's sewage as shown by the average analysis of 262 samples evenly distributed throughout the year, the proportion was 50 per cent. Let us take 45 per cent. as the average. If we can remove 30 per cent. of the soluble organic matter, and all of the suspended, we shall leave only 70 per cent. of the 55 per cent. soluble organic matter, or 38 per cent. of the whole; while, if we remove 40 per cent. of the soluble organic matter, the amount left will be only 33 per cent. of the whole.

Of the other substances present, the insoluble inorganic matters, mainly sand, are removed almost completely, while the soluble salts, including chloride and free ammonia, are not affected in the least, excepting that the acid of the precipitant remains in solution, in combination with the alkali of the sewage. A very large proportion of the bacteria and of the other organisms is removed.

RELATIONS OF SEWAGE AND THE EFFLUENTS FROM CHEMICAL PRECIPITATION TO THE GROWTH OF BACTERIA AND ALGÆ.

When a nuisance is produced by sewage in any way, the direct cause is usually the development of organisms fed by the organic matter and nitrogen of the sewage. To secure the absence of organisms in any pond or stream, where food is present, is a hopeless task. It thus happens that, while the organisms are the real cause of the trouble, their removal from sewage is often of less importance than the removal of the matter in the sewage on which they feed. The proportion of organic matter removed does not necessarily represent the proportion of food for organisms removed, for some kinds of organic matter are no more suitable food for bacteria than is sawdust for horses. An effluent from a sewage filter, where nitrification is complete, containing 2 per cent. of the total organic matter of the sewage, will not serve as food for bacteria, because it has been worked over already by bacteria in the filter, and nearly everything available has been removed. If, on the other hand, sewage is mixed with fifty times its volume of pure water, so that it contains the same amount of organic matter as the effluent, the bacteria will increase enormously for a few days. From this point of view, the effluent is many times purer than is indicated by the ratio of its organic matter to that of the sewage.

With sewage precipitation the case is entirely different, for in it there

is no bacterial action. There is, however, some reason to think that the organic matter left is not so good a food, and, therefore, not so dangerous as that removed. Sewage settled alone will keep turbid with organisms, and in a day or two masses of zoogloea separate from it. Sewage precipitated by either copperas, ferric sulphate, or alum, in suitable quantities, has repeatedly remained so clear that the bottom of the barrels could be distinctly seen through more than two feet of liquid, for one or two weeks. In these cases no flakes of zoogloea so characteristic of untreated sewage have been seen, and the odor is much less than that of sewage alone.

This question of the qualities of the organic matter left by precipitation has not been sufficiently investigated, but the indications are, that it is worse than the same amount in the effluent of sewage filtration through sand, but less objectionable than that of sewage.

When untreated sewage is put into a small stream or pond, it often happens that the suspended matters settle out, forming considerable deposits, which, putrefying out of contact of the air, give rise to very offensive gases. It is hardly probable that well-precipitated sewage would do this, for almost no suspended organic matter is present when it leaves the settling tank, and very little soluble matter is precipitated on exposure to the air.

Another nuisance which might be caused by putting precipitated sewage into a stream or pond, is the growth of algæ, fed by the ammonia of the sewage. It may be said, however, that this growth would be no greater than that caused by the crude sewage, and probably not much greater than that caused by filtered sewage; for, in the latter case, while the ammonia is removed, nearly an equivalent of nitrate is formed, and this serves as food for algæ almost as readily as ammonia.

A number of fishes have been put into precipitated sewage. In each case the fish has died within five minutes. This sudden death cannot be due to the chemicals used, for it was found that they lived for a considerable time in solutions of the chemicals much stronger than those present in the sewage. The fishes died for want of air. Sewage contains no dissolved oxygen, and, if any is absorbed from the air, it is quickly taken up by the organic matter. The precipitated sewage also contains no oxygen.

Conclusion.

Summing up our most important conclusions we have found that using lime as a precipitant, there is a certain definite amount of lime, depending upon the composition of the sewerage, which gives a better result than less, and as good or a better result than more. This amount of lime is that which exactly suffices to form normal carbonate with all the carbonic acid of the sewage. It is possible in a few minutes, by simple titration, to determine, approximately the amount of uncombined carbonic acid present in sewage, and how much lime will be required to combine with it. It is also possible to determine in a similar way, after mixing, whether enough or too much lime has been added. The amount

of lime required by Lawrence sewage averages about 1,600 pounds per million gallons.

Ordinary house sewage is not sufficiently alkaline to precipitate copperas, and a small amount of lime must be added to obtain good results. The quantity of lime required depends both upon the composition of the sewage, and the amount of copperas used, and can be calculated from titration of the sewage. Very imperfect results are obtained with too little lime, and, when too much is used, the excess is wasted, the result being the same as with a smaller quantity.

After mixing the sewage with both copperas and lime, if enough or too much lime has been used the mixture will color phenolphthalein red, while, if too little has been used, no color will be produced. This test can conveniently be used by people having no knowledge of chemistry, and affords an easy and very accurate method of applying enough lime and of avoiding a useless excess.

Using in each case a suitable amount of lime, the more copperas used the better the result; but, with more than one-half a ton per million gallons the improvement does not compare with the increased cost.

Some acid sewages contain a considerable amount of iron in solution, and in these cases precipitation by lime is really the rendering available of the copperas already in the sewage, and so is properly classed as an iron treatment rather than a lime treatment. In this case the reaction with phenolphthalein shows the presence of enough lime.

In precipitation by ferric sulphate and crude alum, the addition of lime was found unnecessary, as ordinary sewage contains enough alkali to decompose these salts. Within reasonable limits the more of these precipitants used the better is the result, but with very large quantities the improvement does not compare with the increased cost.

Using equal values of the different precipitants applied, under the most favorable conditions for each, upon the same sewage, the best results were obtained with ferric sulphate. Nearly as good results were obtained with copperas and lime used together, while lime and alum each gave somewhat inferior effluents. The range of these results was, however, comparatively narrow; and it may be that, with sewage of a different character or with variations in the prices of the chemicals, it would be advantageous to use copperas with lime or even alum. When lime is used there is always so much lime left in solution that it is doubtful if its use would ever be found satisfactory except in case of acid sewage. It is quite impossible to obtain effluents by chemical precipitation which will compare in organic purity with those obtained by intermittent filtration through sand.

It is possible to remove from one-half to two-thirds of the organic matter of sewage by precipitation with a proper amount of an iron or aluminum salt, and it seems probable that in some cases at least, where the conditions for intermittent filtration are unfavorable, and a high degree of purity is not required, by carefully observing the conditions of successful precipitation, a result can be obtained which will effectually prevent a public nuisance.

THE LATE SUSPENSION BRIDGE OF MINNEAPOLIS.

By F. W. Cappelen, Member, Engineers' Club of Minneapolis.

[Read April 6, 1891, at a joint meeting of the St. Paul and Minneapolis Clubs.]

Gentlemen of St. Paul:

I have to ask your indulgence for choosing a Minneapolis subject with which to entertain you, and expect that the members of my club will show me considerable leniency for talking about a structure they are so familiar with as the late suspension bridge; but I do hope that I may be able to tell you all something that may be of interest and perhaps of some professional value.

In the year 1848, Mr. R. P. Russell built the first dwelling house in St. Anthony, and in 1850, Col. Stevens built the first one in Minneapolis. Communication between the two towns was by ferry in summer and by ice in winter. So rapidly did these settlements grow, however, and the pioneers were such hustlers, that in 1854, Franklin Steel, H. T. Welles and others, formed the Minneapolis Bridge Company, and built the first suspension bridge, and I understand that this bridge was the first that spanned the "Father of Waters,"—the great Mississippi.

The accompanying sketch gives some idea of the structure. The span was 560 feet, 16 feet roadway, no sidewalks, wooden towers on stone foundations. The engineer was Mr. Thomas M. Griffeth of whom we shall hear later. The bridge was located on the site of the present steel arch and was a toll bridge, the following charges being made:—

For each foot passenger	$ .05
Horse, mare or mule, with or without driver	.15
Two horse, two mule or two ox team, with or without driver	.25
For each additional horse, mule or ox	.10
Single horse carriage	.25
Cow or ox	.10
Sheep or swine	.02

The bridge was well patronized and after two years the collections amounted to $12,500 a year. If the same toll and rates were to be collected to-day at the same place they would amount to about $4,000 per day. It may be of particular interest to the St. Paul gentlemen to know that the first castings made in the state were for this bridge, and were made by Gilman of St. Paul. The elevation of the roadway was 100 and the

city datum is established accordingly. The capacity of this structure became too small in course of time, and in February 1875, the City Council of Minneapolis engaged Thomas M. Griffeth of Lewistown, N. Y., at the rate of $5,000 yearly salary, to build a new bridge.

The general plan agreed upon was a suspension bridge of 670 feet span, 20 feet clear roadway and two 6-foot sidewalks. The elevation of the roadway was about 120, so that the new bridge could be built without interfering with travel. The bridge was opened for travel in the winter of 1876 and 1877. But already in a few years time the sidewalks had to be widened, and in 1884 steps were taken to get additional bridge facilities at the crossing next to and paralleling the suspension bridge. In 1888 the first half of the steel arch was built, up stream, within 6 inches of and parallel with the suspension.

THE SUSPENSION BRIDGE No. 2.

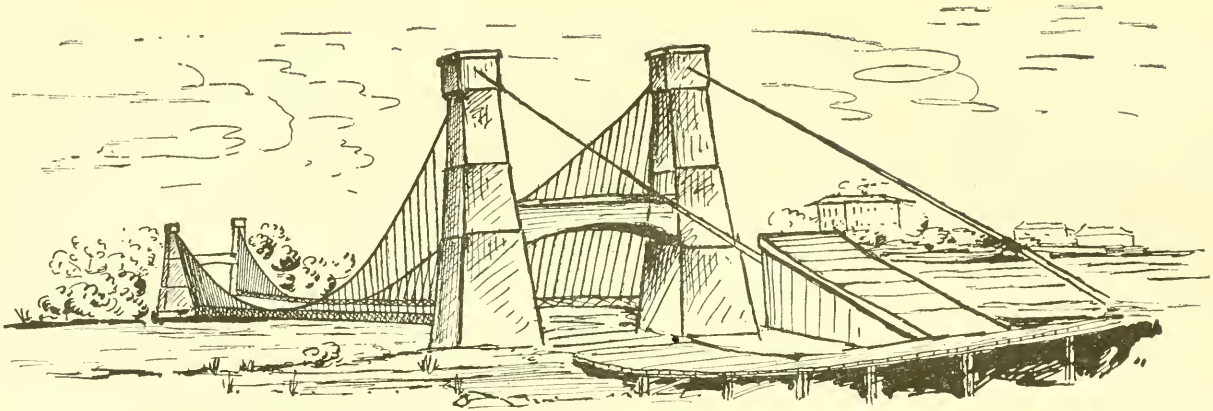
Substructure.

Towers.—The east side towers were founded on the white St. Peter sand rock at an elevation of 84, that is, at the present low water level of the river. In constructing the east abutment of the steel arch I excavated two feet below the lower foundation, in the sand rock, close up to the old masonry, and found that the lower foundation consisted of concrete, three feet thick, in excellent condition. From foundation to street grade was about 40 feet and from street grade to top of the tower 70 feet, making a total height of 110 feet. The base of the foundation was 20 feet square, at street the tower was 13 feet square, thence stepping off in an ornamental manner so as to be 10 feet square on top, with small ornamental towers on all corners as seen by plan. Center to center of towers was 35 feet, this being the distance between cables at this point. The cables cradled toward each other until, at center of span, they were 22 feet and 6 inches apart. The west towers were founded on the lime rock ledge at an elevation of 114.

Anchor Piers.—The anchor piers were about 40 feet long, 10 feet wide and 10 feet high. The first 20 feet enclosed the anchor links solid, but the last 20 feet of the pier was hollow, leaving quite a room inside to be used by watchman and for storage. This masonry was probably carried down to the ledge through which the links were carried, fastening their anchor plate on the lower side of the ledge. The ledge at this point was about 10 feet thick. The same condition existed on both sides of the river as far as the anchorages are concerned. Probably this very ledge, giving such splendid facilities for anchoring was mainly the reason for adopting the suspension style of bridge, as long as the United States would not permit piers to be built in the river.

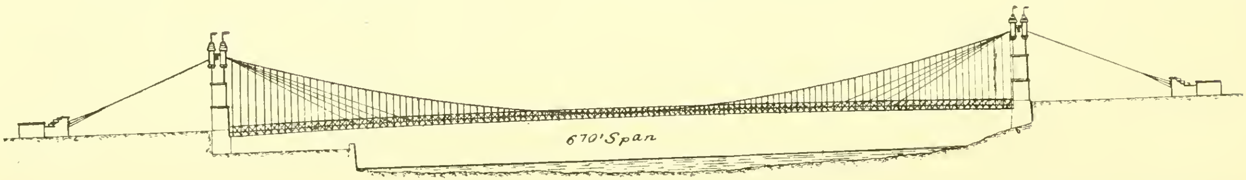
The masonry consisted throughout of native blue limestone with granite trimmings laid in cement. The price paid per cubic yard was $11.00. The work was apparently put up in good shape. There were also 4 guy piers, two on each shore, on about 60 to 80 cubic yards capacity. The span was guyed to these piers by ¾″ wire ropes.

I referred above to the splendid facility for anchorage and will explain



THE FIRST BRIDGE ACROSS THE MISISSSIPPI.

Built by the Minneapolis Bridge Co., at Minneapolis, Minn., 1854-55. Thos. M. Griffeth, Engineer.



SUSPENSION BRIDGE NO. 2.

why. The blue lime rock ledge rests, as you all know, on the sand rock. After locating the position of the anchor plates, a tunnel was dug under the ledge through the sand rock, large enough to permit the handling of the anchor plates. The ledge was cut through wide enough to permit the links to pass through. The anchor plates were then lifted up under the ledge and connected with the links.

Superstructure.

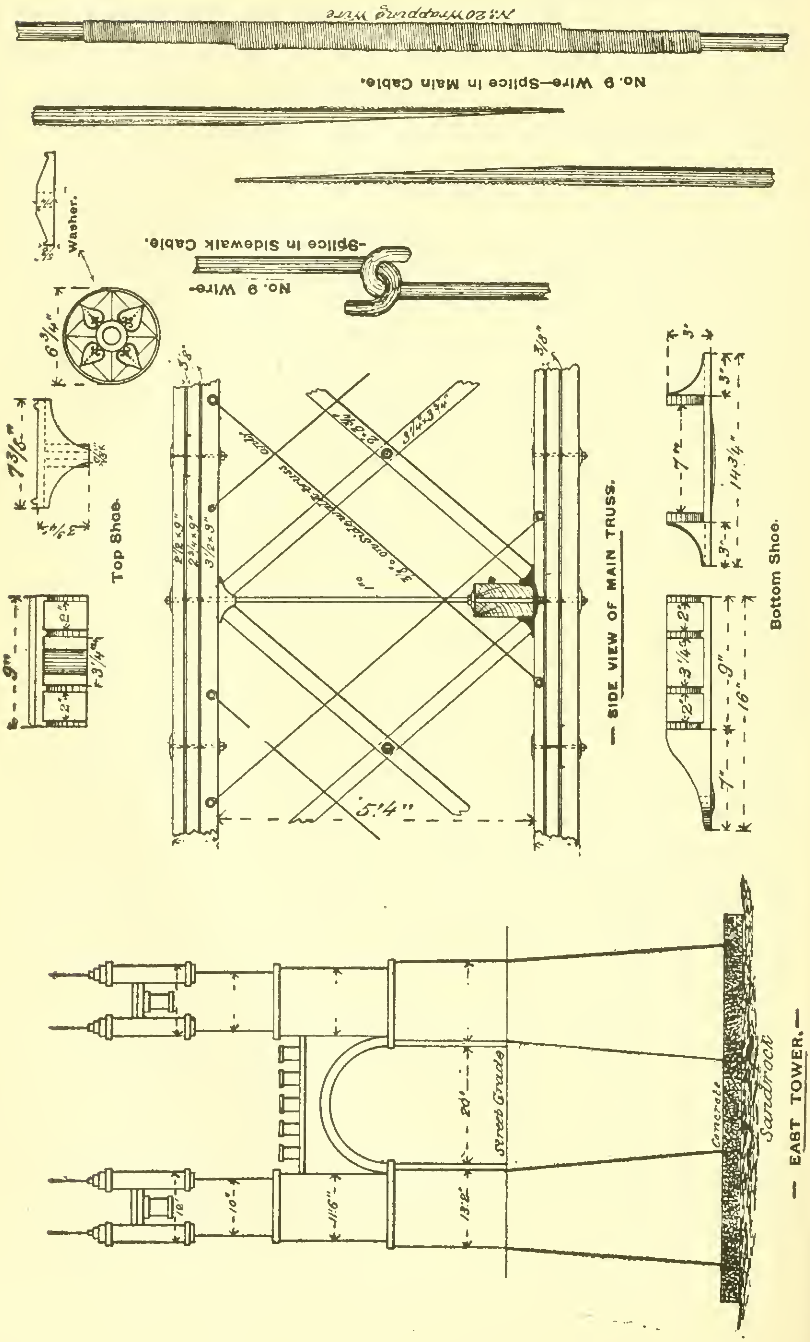
Cables.—The roadway proper was carried by two main cables and the outer portion of the sidewalk by one cable on each side. The main cables consisted of 3,150 wires, No. 9, Birmingham gauge, and the sidewalk cables each of 450 wires, same kind as in main cables The main cable wires were wrapped with No. 12 wire, the sidewalk cable with No. 15. Before wrapping, the wires were thoroughly oiled and after wrapping, puttied and red-leaded. The main cable, 10″ in diameter, including wrapping, passed thus over the tower on a cast iron expansion shoe, to within 22 feet of the anchor pier, where it separated into 7 cables of 450 wires each, same as sidewalk cable each separately wrapped. These seven cables and the sidewalk cable, as well as two stay cables, entered the anchor piers through large cast plates. The two stay cables divided on the other side of the tower into two smaller stays, making four stays altogether, each of 77 wires. These connected with the floor, the first one about 105 feet from the tower and the other three each 20 feet further out. Where the stays connected, a six-inch octagon wooden strut was placed from floor to cables, and the main cables were cradled at these points by wire stays between them.

Floor System.—The floor beams consisted of 2—3½″ × 12″ pine planks, 1″ apart on five feet centers, supported by suspenders from the cables, center to center of supports being 22 feet and 8 inches. The outer end of beam on outside of sidewalk, was similarly connected to the sidewalk cables, as indicated on sketch.

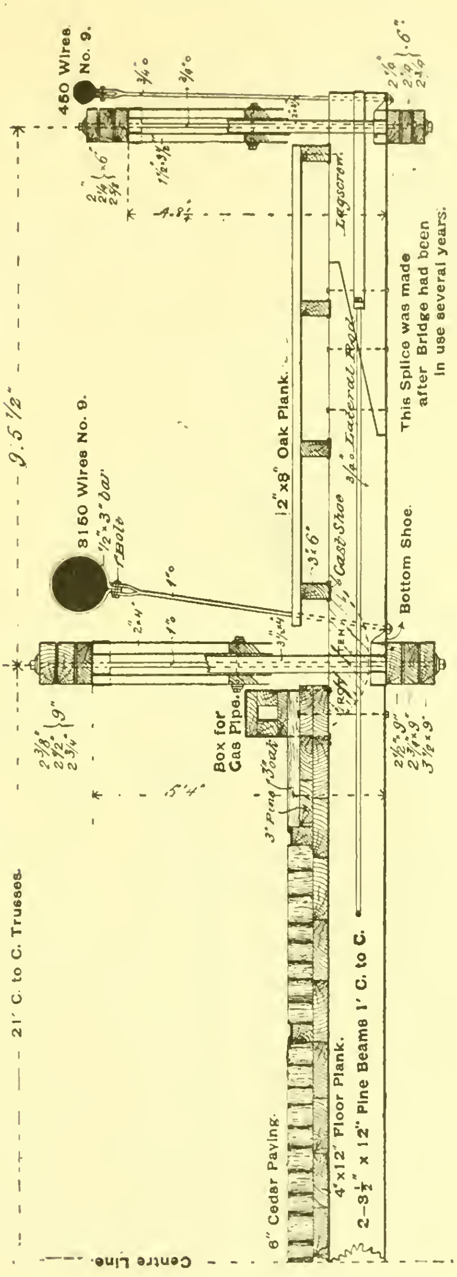
The floor proper was 4″ × 12″ pine plank, scant, running longitudinally. Upon this planking a wooden block pavement was laid. This pavement had one rather unique feature about it worth mentioning. The blocks were 4″ × 6″ × from 10″ to 12″, 6″ being the thickness. Lengthwise of the block, on its bed, a 1″ round groove was cut to permit air circulation. I will leave it to you, gentlemen, to determine the draft of air after the joints were filled and tarred.

The sidewalk floor consisted of 3″ × 6″ pine joists on 2′—8″ centers, supporting a 2″ oak floor. Great care was taken to prevent rotting, small cast iron shoes being framed into the beams, and the joists being placed on these shoes and lag screwed to beam.

Stiffening Trusses.—There were 4 trusses, 2 for the roadway on 21′ centers and 2 for the sidewalk, one on each side. These trusses acted also as railings. The roadway truss bottom chord was made up of 1—3½″ × 9″, 1—2¾″ × 9″, 1—2½″ × 9″, and the top chord of 1—2¾″ × 9″, 1—2½″ × 9″, 1—2⅜″ × 9″ throughout the entire length of span, and for 175′ at


No. 20 Wrapping Wire
No. 9 Wire—Splice in Main Cable.
No. 9 Wire-Splice in Sidewalk Cable.
Washer.
Top Shoe.
SIDE VIEW OF MAIN TRUSS.
Bottom Shoe.
Street Grade
Concrete
Sandrock
EAST TOWER.

HALF CROSS-SECTION.



both ends an additional piece of $3\frac{1}{2}'' \times 9''$ for bottom and $2\frac{3}{4}'' \times 9''$ for top chord was added.

The sidewalk truss had in top chord 1—$2'' \times 6''$, 1—$2\frac{1}{4}'' \times 6''$, 1—$2\frac{5}{8} \times 6''$, and in bottom chord 1—$2\frac{3}{4}'' \times 6''$, 1—$2\frac{1}{4}'' \times 6''$, 1—$2\frac{1}{4}'' \times 6''$, and an additional $2\frac{5}{8}'' \times 6''$ for top chords and $2\frac{3}{4}'' \times 6''$ for bottom chord for 175′ at ends of span.

These pieces varied in length from 7′ to 37′–6″. The distance between chords was 5′–4″ for roadway truss and 4′–8¼″ for sidewalk truss. The chord pieces were separated every two feet six inches by cast iron keys as shown on sketch. Panel lengths, all through, were five feet. Braces of roadway truss were 2—$2'' \times 4''$–7′ long, and 1—$3\frac{1}{2}'' \times 4''$–7′ long, and 1—1″o truss rod. Braces of sidewalk truss were 2—$1\frac{1}{2}'' \times 3\frac{1}{2}''$ and 1—$2'' \times 3\frac{1}{2}''$ and 1—¾″o truss rod. All braces had cast iron shoe bearings and were bolted together in the middle.

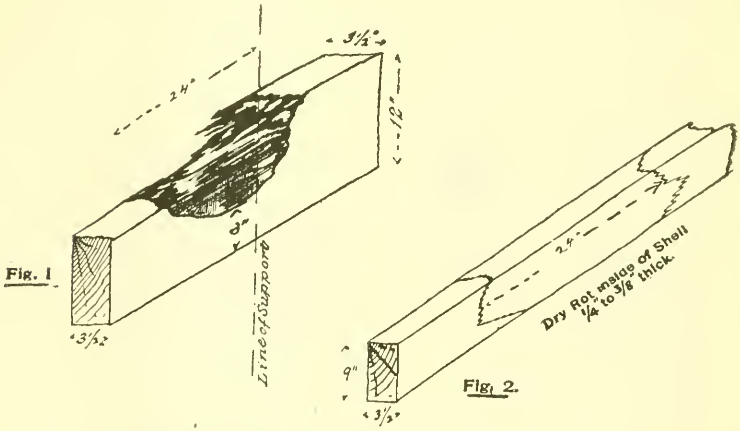


Fig. 1 represents Floor Beam Showing Decay.

Fig. 2 represents Piece of Chord Showing Decay.

Originally two pipe lines (wrought iron) were carried across in boxes next to roadway truss; one 1¾″ pipe for water and one 3″ pipe for gas. The water pipe was discontinued after a submerged water main had been put across the river.

The beams rested on the bottom chord, the tie rod in the truss passing between the two pieces of the beam. The rod had a thread cut so as to screw up beam to chord. Just clearing the chord on the outside, the end of the beam was connected by the suspender to the cable. That portion of the suspender that passed through the beam was an iron rod which again connected with the wire suspender. Only where the cable came down low were the iron rods connected directly to the cable.

The bottom lateral rods, ¾″o, were fastened to an iron clamp at the ends of every 5th beam, and ran through the intermediate beams.

Having this general information you may with more ease follow the tale of the demolishing of "Minneapolis's greatest and most beautiful structure" as the newspapers generally termed it.

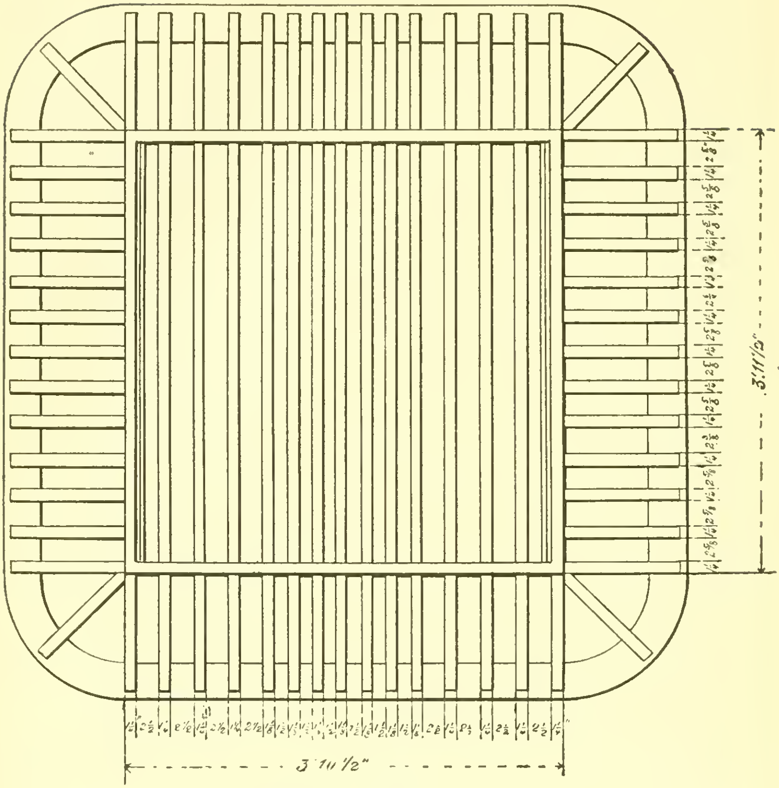
The bridge was very hard to keep in repair; always something wrong; an eye breaking here and a bolt there, and the trusses always loose and rickety. When the beams were spliced to widen the sidewalk I am told there were strong indications of beams rotting, but the trusses seemed all right. I screwed them up several times and they would remain all right for a while, but finally I could do nothing with them and made up my mind that something was wrong. At the lower panel points, galvanized iron coverings had been placed probably to prevent dirt and water from lodging in the shoe connections with diagonals beam and chord. I had them removed, everything cleaned up, and made a thorough examination with the following results:

First 4 beams very bad; 5th: rotten; 6th: one side rotten; 7th and 8th: bad; 9th, all right; 10th to 17th: bad; 18th: good, chord rotten, and so on. This was on the north side, from the east end. On the south side from the west end,—1st beam, fair; 2nd: clean gone; 3rd: rotten clear through; 4th: bad; from here to 20th beam everything gone, and so on. If one beam was fair at one end it was gone at the other. I hereby present to you an average sample. You will notice that the sawed off ends are fair, but that the rest is a picture of perfect rottenness. Every brace was also gone. It may be worth mentioning that the greatest decay occurred on the south side. All beams had a permanent deflection of from 1″ to 1½″.

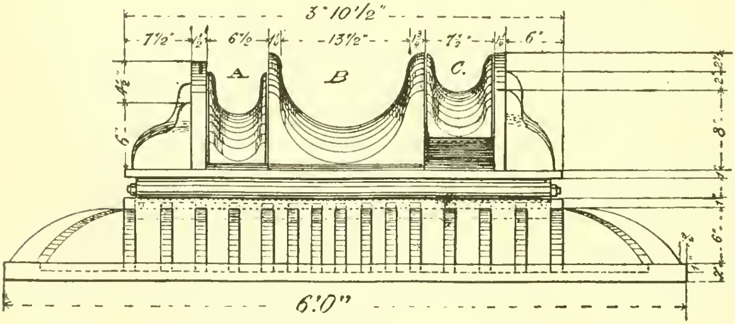
I reported the matter and the bridge was ordered closed. Examine that beam and consider it might any day have been subjected to a fiber strain of from 2,500 to 3,000 lbs., or less than a factor of 2.

In connection with the closing of the bridge, a rather ridiculous mixing of orders occurred. It was exposition time and to give the public ample facilities for buggies, carriages, parades, etc., all heavy teams were ordered off the Steel Arch Bridge and onto the Suspension Bridge, and a huge sign to that effect put up. At about the same time, a little later, came another order that all heavy teams must take the Steel Arch Bridge because the Suspension Bridge was not safe.

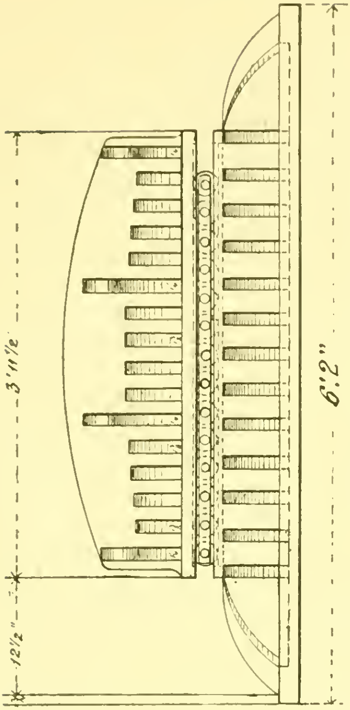
Now something had to be done, either repair the bridge or take it down and complete the Steel Arch. A tremendous howl came from the newspapers, figures of cost, etc., were misquoted, and there was no end of trouble all around. The City Council finally decided to advertise for the completion of the Steel Arch, for the repairing of the Suspension Bridge and for the removal of the Suspension Bridge, and by a motion of some alderman, (offered in earnest) the City Council was actually instructed to make a survey of the gulch of Minnehaha Creek at the Soldiers' home, with the object in view of putting the Suspension Bridge up there. The survey was made and the Suspension Bridge found to fit at a cost of $60,000, but an iron viaduct could be put up at the same place for $32,000, so that settled the Suspension Bridge scheme, as far as Minnehaha gulch was concerned. The following are the specifications:



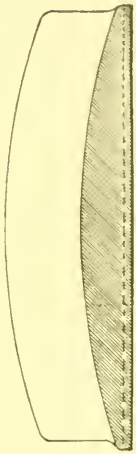
PLAN OF SHOE.



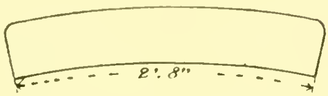
END VIEW OF SHOE AND SADDLE.



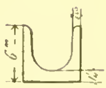
IDE VIEW OF SHOE AND SADDLE.



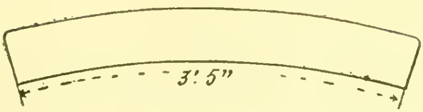
Section of B.



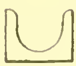
Box A Side View.



Section.



Box C. Side View.



Section.

Specifications

For the Removal of the Suspension Bridge over the Mississippi River in the City of Minneapolis.

The work to be done under these specifications is the entire removal of the Suspension Bridge, including roadway structure, all cables, stays, etc., and all masonry towers and anchor piers to a depth of 2 feet below the present street grades. The removal must be done in such a manner and at such a time as not to interfere with the erection of the new work of the Steel Arch, either sub-structure or superstructure. No work whatever can be done from the Steel Arch, and the piling of material on either approach will not be permitted to interfere in the least with the public traffic.

The following are the approximate quantities of different material contained in the structure:

Lumber	180,000 ft. B. M.
Limestone masonry	1,300 cu. yds.
Granite	132 " "
1928 ft. of 10″ cable	330,000 lbs.
1928 ft. of 4″ "	61,000 "
Suspenders and stays	34,000 "
Iron rods (such as lateral rods, stiffening rods, suspender rods) ties and bolts	31,000 "
Cast iron washers, splice plates, angle blocks, keys and shoes	50,000 "
Total	506,000 lbs.

This does not include bearing shoes of cable on towers nor the iron work which is inside of anchor piers as there is no way of determining same.

The entire lot of material to become the property of the contractor. The contractor must state a price he will pay the City of Minneapolis for removing the structure and to become the owner of the above mentioned material.

I will give you next the specifications for the repair of the Suspension Bridge in order to show that I do not consider the price asked for doing the work excessive; and also to call your attention to a few points worth discussing.

Specifications

For the Repairing of the Suspension Bridge Over the Mississippi River in the City of Minneapolis.

The work to be done under these specifications is the removal of the present woodwork of the suspension bridge and repairing same with new lumber. The entire framing to be done so as to fit all present castings, rods, etc. The new structure to be made an exact duplicate of the pres-

ent one with the exception of the floor beams and floor plank which will be as specified later.

All framing must be done in a workmanlike manner, all joints to be as tight fitting as they possibly can be made. If any part of the iron work such as bolts, nuts, washers, splice plates, angle blocks, etc., are lost during the work, new ones must be furnished of the exact pattern as the remaining pieces of the many different special kinds. And if any such pieces should be gone or impaired, the contractor must furnish new ones and also repair any iron work that needs repairing.

BILL OF MATERIAL.

Roadway Truss.—

Top Chord.	Bottom Chord.
1—2½″×9″×22.8′	1—3½″×9″×27.5′
1—2½″×9″×17.2′	1—3½″×9″×12.5′
21—2½″×9″×30′	21—3½″×9″×30′
1—2¾″×9″×32.8′	1—2¾″×9″×37.5′
1—2¾″×9″×7.2′	1—2¾″×9″×32.5′
21—2¾″×9″×30′	20—2¾″×9″×30′
1—2⅜″×9″×12.8′	1—2¾″×9″×17.5′
1—2⅜″×9″×27.2′	1—2¾″×9″×22.5′
21—2⅜″×9″×30′	21—2¾″×9″×30′
Braces.	1—2½″×9″×12.5′
268—2″×4″×7′	1—2½″×9″×30′
134—3½″×4″×7′	10—2½″×9″×30′

Two trusses like this. All lumber surfaced 4 sides to the exact dimensions. Panel length 5 feet. Cast keys every 2′–6″.

Sidewalk Truss.—

Top Chord.	Bottom Chord.
1—2″×6″×22.8′	1—2¾″×6″×27.5′
1—2″×6″×17.2′	1—2¾″×6″×12.5′
24—2¼″×6′×32.8′	21—2¾″×6″×30′
1—2¼″×6″×7.2′	1—2¼″×6″×37.5′
21—2¼″×7″×30′	1—2¼″×6″×32-5′
1—2⅝″×6″×12.8′	20—2¼″×6″×30′
1—2⅝″×6″×27.2′	1—2¼″×6″×17.5′
21—2⅝″×6″×30′	1—2¼″×6″×22.5′
	21—2¼″×6″×30′
Braces.	1—2¼″×6″×12.5′
268—1½″×3½″×7′	1—2¼″×6″×12.5′
134—2″×3½″×7′	10—2¼″×6″×30′

Two trusses like this. All lumber to be surfaced 4 sides to the exact dimensions. Panel length 5′. Cast keys every 2′–6″.

Floor Beams.—

270 pieces 3½″×16″×41′. Surfaced 4 sides.

Roadway Planking.—

16 pieces—5″ × 12″ × 10′
528 pieces—5″ × 12″ × 20′
6 pieces—4″ × 10″ × 10′
198 pieces—4″ × 20″ × 20′
270 pieces—5″ × 12″ × 2′ fillers.
1340 pieces—2½″ × 12″ × 2′ 6″. Oak top planks.

All lumber surfaced to exact thickness.

Sidewalk Joist.—

8 pieces—3″ × 6″ × 10′ s. 4 s.
264 pieces—3″ × 6″ × 20′ s. 4 s.
2030 pieces—2″ × 8″ × 8′6″ s. 1 s. and 2 e. Oak sidewalk plank.

Guard Rail.—

1—8″ × 8″ × 10′
34—8″ × 8″ × 20′

Guard Rail Pipe Box.—

$$\left.\begin{array}{r} 2—2'' \times 8'' \times 10' \\ 66—2'' \times 8'' \times 20' \\ 2—2'' \times 4'' \times 10' \\ 66—2'' \times 4'' \times 20' \end{array}\right\} \text{s. 1 s. and 2 e.}$$

The floor beams are suspended directly from the cables by the suspenders. The trusses are connected to the floor beams by the tie-rods. The 5″ × 12″ roadway plank must break joints on the floor beams and are to be fastened to the floor beams with 4—8 lag screws, heads to be sunk in flush. The 4″ × 10″ roadway plank to be spiked to fillers in the same manner as the 5″ × 12″ roadway plank is fastened to the floor beams. The top oak plank must be fastened to the floor below with 4—6″ lag screws and at every beam on one side a ¾ bolt must be run through the oak plank, the 4″ floor plank, the filler, and catch the lower side of the floor beams with a 4″ cast washer for one end, and 3″ cast washers for the other end.

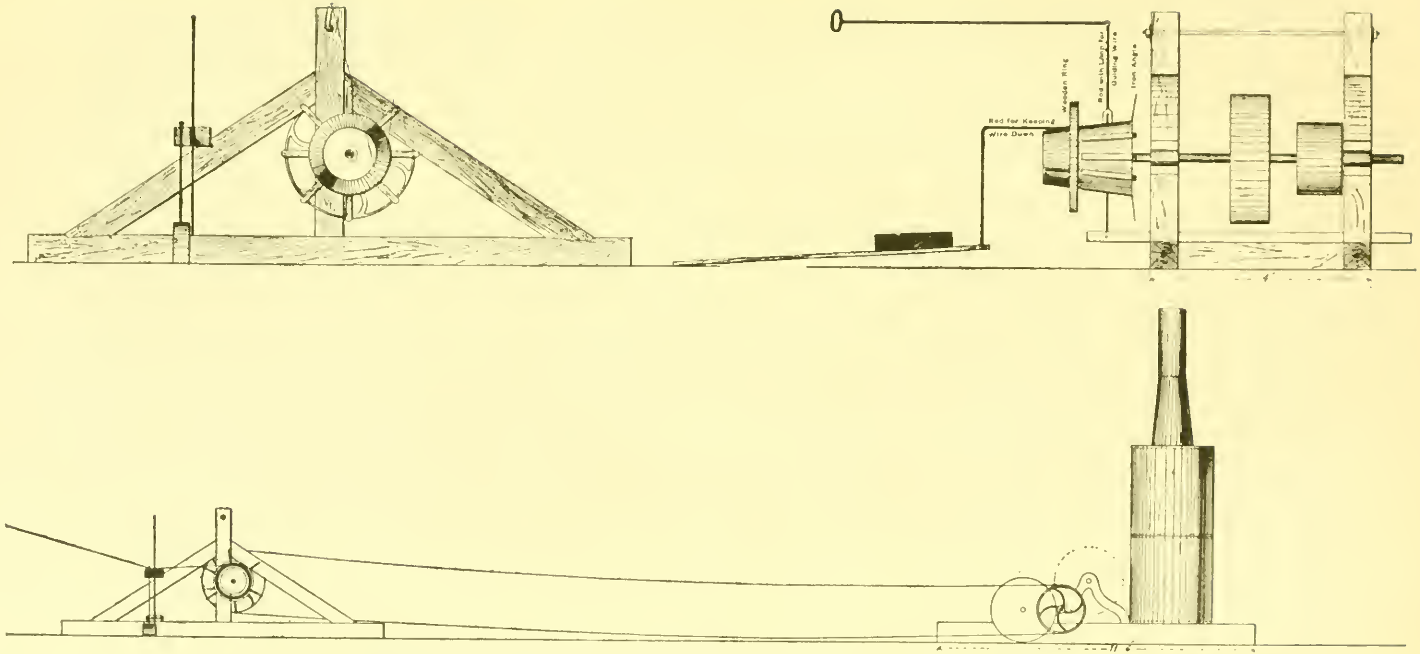
The sidewalk joists are framed into a cast shoe at every beam, and fastened to beam with 9″ lag screws. The box guard is fastened to floor below with iron straps run through the screw ends and nuts at bottom ends.

Lumber.

All lumber with the exception of the oak must be first common white pine, or equally as good, free from sap, bad knots and waney edges, and all lumber with exception of floor planks must be kiln-dried. All oak must be white oak, equal to first common in grade, and free from bad knots and waney edges.

Painting.

All iron work including the cables must receive one coat of good paint of color and brand as directed by the City Engineer. All iron work that will be hidden or framed into the woodwork must receive the paint before being framed. All trusses, sidewalk joists, and for 12 feet on each end



WINCH USED FOR WINDING UP THE CABLE WIRE.

of floor beams, must receive two good coats of paint. All points not accessible after framing must be painted before framing.

Total amount of lumber about 215,000 ft. B. M. There are about 6,500 pieces of cast iron shoes and keys to be framed in, weighing about 43,000 lbs. Then there are about 26,000 lbs. of iron to handle in connecting trusses, beams, etc., with each other and with the suspenders.

The contractor must furnish all material and labor required.

Then follow the general specifications for six inch cedar block paving, which it is not necessary to mention.

The estimated cost of the masonry required to complete the Steel Arch was about $10,000. We received one bid for repairing the Suspension Bridge, viz. $17,000. My estimate was $17,003. There were a good many bidders looking the matter up, but they somehow were afraid to tackle the job. We got one informal bid, offering the city $5,000 for the bridge, by Janney, Semple & Co., of Minneapolis, and one combination bid by Arthur McMullen & Co., of Minneapolis, offering to complete the sub-structure of the Steel Arch and to take down the Suspension Bridge for $4,000, that is to say, they gave us about $6,000 for the Suspension.

The low bid of $72,800 for the second half of the superstructure of the Steel Arch, settled the fate of the Suspension Bridge and the contract for its removal was awarded to McMullen & Co., who, as soon as the river froze over, commenced the work. They sublet the work of taking down the roadway to Balch and Weatherby, who, after removing the paving and planking, started in the middle of the span by unscrewing all rods and bolts for say, 10 to 15 feet, having this section secured to the cables by blocks and tackle; then the chords were sawed off and the section lowered to the ice where the iron was separated from the lumber, which was generally done by smashing everything that would not come apart easily.

The sub-contractor took down this portion of the structure for the keeping of the lumber and had to haul all iron to some storing place.

This work was done at a cost of about $430.

The taking down of the cables was delayed for a considerable time, the principal reason being, I think, to find a buyer who would also take the wires down. No satisfactory arrangement could be made however and Mr. McMullen made up his mind to do it himself.

Before the letting of the work I expressed my opinion to the several prospective bidders as to how to take down the cables, seeing no particular reason why my scheme should not work although I had no approved plan to imitate. I suggested putting up a steam engine and simply to pull the single wires out, winding them on a drum. Each wire, being about 975 feet long and weighing about 50 lbs., would make about the proper sized coil. Well, the idea was adopted, and the hoisting engine was put up at the farther end of the anchor pier (west). The drum with attachment to handle the wire and wind it up was placed and fastened at the nearer end of the pier and as close to the line of the cable as practicable.

Work was commenced on the south sidewalk cable, the cable first be-

ing unwrapped and then cut at the east pier and the loose end held by blocks and tackle. Then the strands were cut at the west end and the strands one by one fastened to the drum and pulled through.

The work went along rather in bad shape at first, too many wires having been cut. The splices of the different wires were in many cases made simply as hooks. The wires would catch somewhere, double, break and tangle and in a short time there was a pretty mess. Wires everywhere, single and in bunches, tangled and straight; and, in trying to pull some apparently clear wires, matters grew worse. It certainly looked as if the plan was impracticable.

We considered several schemes, but could not see a better way out of it. So we cut the tangled mass, got matters straightened again and commenced anew taking care not to have too many loose wires. We got along a little better and tackled the main cable. Judging from the position of the wires in the center of the span, one would think that the wires would keep that position fairly well through the rest of the cable; but we were sadly disappointed; a wire on top of the center of span would appear on bottom near the anchorage and vice versa. We then cut, as near as we could judge, a certain number of wires at both ends and loosened such a bunch as far as possible from the rest by inserting iron bars and working these bars up along the cable. The first bunches were the hardest to handle; afterwards matters went easier. The men, of course, became more experienced.

The accompanying sketch explains itself. The end of the wire to be pulled was put under the holding down rod, through the loop of the vertical rod, to the pulley where it was fastened. The vertical rod turned around its lower end as a center so that the wires could be distributed over the conical pulley. The wooden ring was loose, simply held in place by a wedge, and removed when the wire was all coiled. Each coil was tied with a piece of wrapping wire. It took seven days to take down the sidewalk cable.

The crew consisted of

4 laborers	7 days=28 days	@$1.75 per day=	$ 49.00
1 foreman	7 " = 7 "	@ 3.00 " " =	21.00
1 team	2 " = 2 "	@ 3.50 " " =	7.00
1 engine and engineer	7 " = 7 "	@ 5.00 " " =	35.00
Coal and oil, etc		=	15.00
			$127.00
10% on tools, etc		=	12.70
			139.70

450 wires removed makes the cost per wire very close to 31 cents.

The crews were doubled when work commenced on the south main

cable, one crew at the east end and one at the west end. It took just 17 days to take down this cable or

119 days labor@$1.75	$208.25
34 " foreman@$3.00	102.00
34 " engine and engineer@$5.00	170.00
17 " team@$3.00	59.50
Coal and oil	60.00
Mr. Webster 17 days@$2.00	34.00
	$633.75
10%	63.37
	$697.12

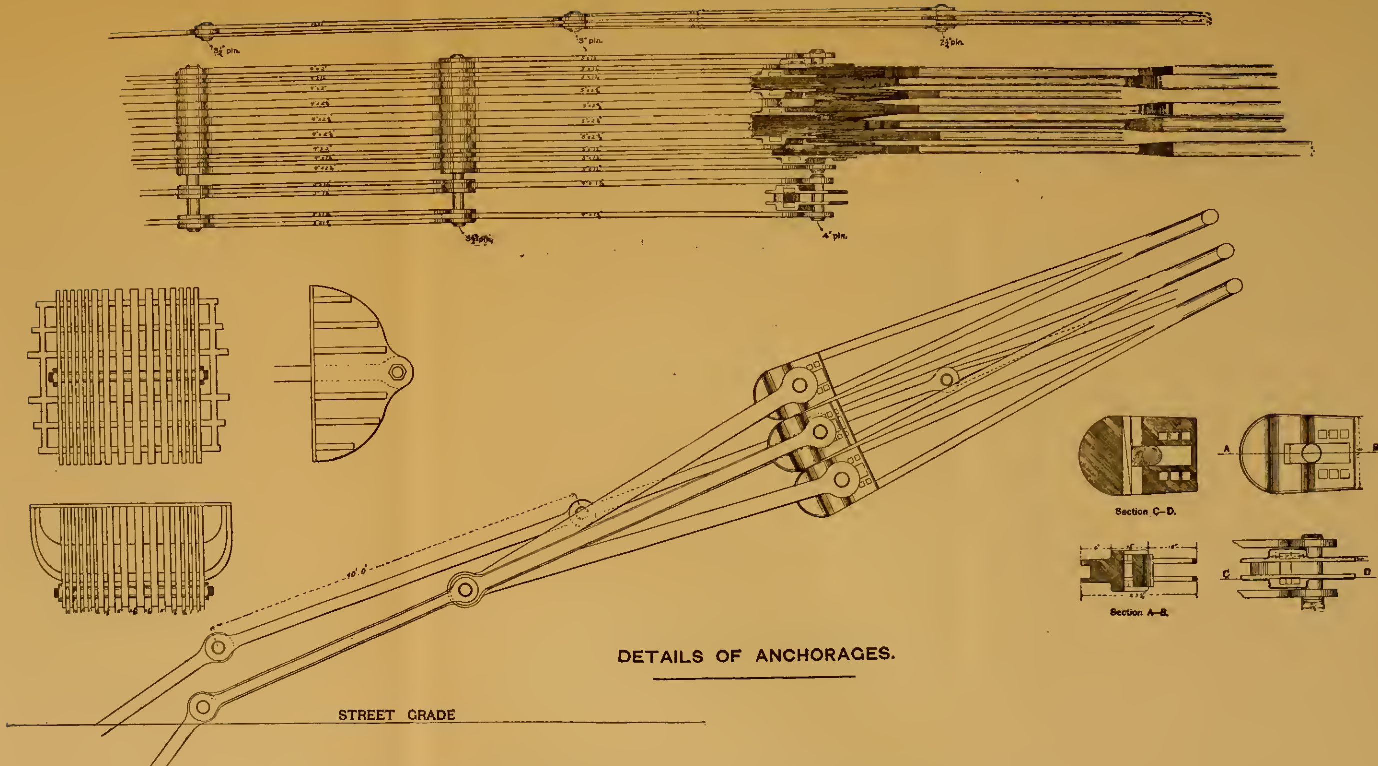
This man Webster was an old blacksmith who had been connected with the erection of the bridge and who, of course, knew all about it.

Well, 3,150 wires at $697.12 makes the cost about 22.13 cents per wire which is quite an improvement, not only in regard to cost, but also as far as material saved is concerned.

The second main cable and sidewalk cable were taken down in the same time as the first main cable and at a cost per wire of 18.5 cents. Averaging it up we have 20.8 cents per wire (say of 50 lb. weight) or the cost per pound of taking down cable amounts to 0.416 cents.

It may be proper and interesting here to consider the wires in detail. As I stated before, the wires both in main cable and sidewalk were No. 9, English standard gauge and supposed to be of charcoal iron and to stand an ultimate strain of 1,500 lbs. In fact, I am told that samples of every coil were tested in Minneapolis before the wire was put in place. Every two wires were spliced. That is to say, suppose we hold the end of our wire at the east end anchorage, bring the other end over the towers to the west anchorage around the proper casting at the anchor links, and thence back again over the towers to the east end, then connect up the two ends in a splice.

In the main cables these splices were made very carefully as shown on sketch and by this sample. The total length of splice is 6 inches, of which for 3 in. from the end of each wire, the wires are cut in wedge shape and corrugated to receive a No. 22 wrapping wire. The wrapping is then extended 1½ in. beyond the splice on each side. I took some of these splices over to the State University and had them tested in an Olsen machine through the kindness and assistance of Prof. Barr. Not having proper grips it was rather difficult to get a good test, but I consider the following two tests good, one of the splice, and one of the solid wire. The spliced wire broke at the splice at 1,500 lbs. although it had not a full section at this point of fracture. The solid wire broke at 1,620 lbs. and showed at the fracture a reduction in area of 29.3 per cent. I could not determine the elastic limit nor the elongation. At the rate of 1,620 lbs. the metal shows for this particular wire, whose area was 0.0179□", an ulti-



DETAILS OF ANCHORAGES.

THE LATE SUSPENSION BRIDGE OF MINNEAPOLIS, MINN.

mate strength of 90,000 lbs per □ inch, which corresponds fairly with a Trenton wire.

These splices were made by hand and were quite slow and tedious to make, so I was not surprised to find traces of neglect and a number of splices simply made by bending the ends of the two wires to a hook. This kind of splices was, however, with a few exceptions, only found in the side-walk cables. Total length of wire exclusive of wrapping was 1421 miles.

Calculation of Strength of Cables.

We will first consider the equilibrium of one perfectly flexible chain supported at two points.

We will suppose the weight per unit of length is p and consider this unit infinitely small and call the horizontal projection of this unit of the chain y (fig. 2.) The resultant of the vertical loads will then be $p\,y$ and applied in the center of y. The point S we choose as the lowest one of the chain, that is, the point of the chain where its direction is horizontal.

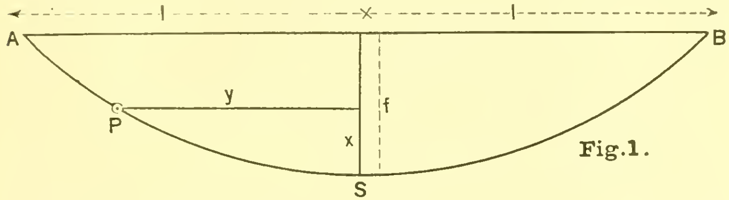


Fig.1.

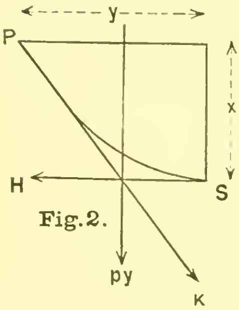


Fig.2.

Suppose we now cut the chain at the points P and S, and consider the portions left and right from P and S removed, then to maintain the equilibrium of the part $P\,S$, forces must be applied at the points P and S and the direction of these forces must be in the direction of the chain at these points, that is, at the point S the force H and at P the force K tangential to the chain at P and S. The piece $P\,S$ is then held in equilibrium by the three forces H, K and $p\,y$, and to maintain the equilibrium these three forces must intersect in one point and the sum of the moments in regard to the point P must be $= o$; or we have:

$$(1) \quad H\,x - p\,y\,\frac{y}{2} = 0 \qquad\qquad (2) \quad H\,x = \frac{p\,y^2}{2}$$

or substituting l and f for y and x we have

$$(3) \quad H f = \frac{p\,l^2}{2}.$$

Now dividing equation (2) by equation (3) we get

$$\frac{x}{f} = \frac{y^2}{l^2} \text{ or } \frac{y^2}{x} = \frac{l^2}{f} = c \text{ the Parabola.}$$

And for the entire chain:

$$(\text{I}) \quad H = p \frac{l^2}{2f} \qquad\qquad (\text{II}) \quad V = p\, l \text{ and}$$

$$(\text{III}) \quad K = \sqrt{V^2 + H^2} \text{ and } (\text{IV}) \text{ tang. } \alpha = \frac{H}{V}.$$

In another way:

(1) $V = p\, y$ (2) $H = c\, p$ assuming c to be of such a length as to make $c\, p = H$.

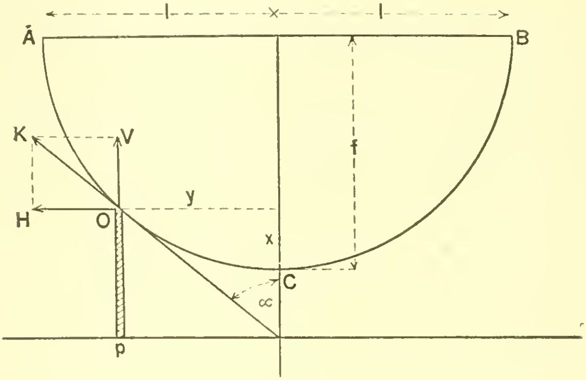


Fig. 3.

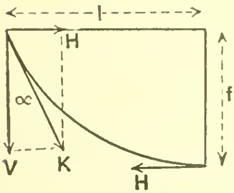


Fig. 4.

$$\text{Tang. } \alpha = \frac{d\,y}{d\,x} = \frac{H}{V} = \frac{c\,p}{y\,p}$$

(3) $\frac{d\,y}{d\,x} = \frac{c}{y}$ or $y\,d\,y = c\,d\,x \quad \frac{y^2}{2} = c\,x$

(4) $y^2 = 2\,c\,x$, the curve is at least close to a parabola.

Call $O\ C = S$. We have then

$$d\,s = \sqrt{d\,x^2 + d\,y^2}$$

$$d\,s = \alpha\,y \sqrt{1 + \frac{d\,x^2}{d\,y^2}} = d\,y \sqrt{1 + \left(\frac{y}{c}\right)^2}$$

and considering that $\sqrt{1 + z} = 1 + \frac{1}{2} z$ for very small values of z we have:

$$d\,s = d\,y \left(1 + \frac{y^2}{2\,c^2}\right)$$

then c is for flat chains very large compared with y, accordingly $\frac{y}{c}$ is very small. Through integration we find:

$$s = y + \frac{1}{2\,c^2} \frac{y^3}{3}$$

and the length of half the chain

$$L = \frac{l}{2} + \frac{1}{2c^2}\,\frac{\left(\frac{l}{2}\right)^3}{3} = \frac{l}{2} + \frac{\left(\frac{l}{2}\right)^3}{6\,c^2} \quad \text{or } L = \frac{l}{2} + \frac{l^3}{48\,c^2}.$$

(5) To find c we substitute in equation (4) above, $y^2 = l^2$ and $x = f$ and get $l^2 = 2\,c\,f$, or (6) $c = \frac{l^2}{2f}$ and further $H = c\,p = \frac{l^2\,p}{2\,f}$ same as (I) above.

$K = \sqrt{c^2\,p^2 + y^2\,p^2} = p\,\sqrt{c^2 + y^2}$ for any point in the chain and K at the support $= p\,\sqrt{c^2 + l^2}$

$$= p\,\sqrt{\left(\frac{l^2}{2f}\right)^2 + l^2} = \sqrt{p^2\left(\frac{l^2}{2f}\right)^2 + p^2\,l^2} = \sqrt{H^2 + V^2}.$$

The two preceding methods making the curve a parabola and H the same in both cases are not strictly correct. The higher calculus gives the following general formulæ for the *catenary* and which hold good for all tensions.

$$(1) \quad S = \sqrt{2\,c\,x + x^2} \text{ and}$$

$$x = \sqrt{c^2 + S^2} - c \text{ and } c = \frac{S^2 - x^2}{2\,x}$$

$$(2) \quad S = \frac{c}{2}\left(e^{\frac{y}{c}} - e^{-\frac{y}{c}}\right) \text{ and } y = c\,Ln\left(\frac{S + \sqrt{c^2 + S^2}}{c}\right)$$

where e is the base 2.71828 of the natural system of logarithms and Ln the logarithm = 2.30258 times the common logarithm.

$$(3) \quad y = c\;Ln\left(\frac{c + x + \sqrt{2\,c\,x + x^2}}{c}\right) \text{ and}$$

$$x = \frac{c}{2}\left(e^{\frac{y}{c}} + e^{-\frac{y}{c}}\right) - c.$$

$$(4) \quad y = \frac{S^2 - x^2}{2\,x}\;Ln\left(\frac{S + x}{S - x}\right)$$

The use of these formulæ is very troublesome, and I will show you that the formula for $c = \frac{y^2}{2\,x}$ as found in the second method is close enough for all practical purposes. We found that:

$$H = c\,p = \frac{y^2\,p}{2\,x} = \frac{p\,l^2}{2f}$$

where H = horizontal strain on chain.

p = load per lineal foot.

l = ½ the span, and

f = the deflection of the chain.

Coming back to my cables I have total weight of span:

Iron,	400,000 lbs.
Lumber,	567,000 lbs.
Paving,	215,740 lbs.

Live load 1,139,000 lbs. at 50 lbs. per sq. ft. for 34′ in width.

2,321,740 lbs.

Span is 670′.

Deflection = $^1/_{12} = \frac{670}{12} = 55.833$ and load per lin. ft. $= \frac{2{,}321{,}740}{670}$ $= 3{,}465$ lbs. We have then:

$$H = 3464 \frac{335^2}{2 \times 55.833} = 3465 \frac{112225}{111.666} = 3465 \times 1005$$

$$H = 3482325 \text{ lbs. and } C = 1005.$$

Taking equation (3) of the higher calculus where

$$y = c\,Ln\left(\frac{c + x + \sqrt{2\,c\,x + x^2}}{c}\right)$$ and substituting for

$y = 335 = \frac{1}{2}$ span.
$c = 1005$ as found above.
$x = 55.833$ we find tha error in y due to this incorrect c, viz.

$$335 = 1005\,Ln\left(\frac{1005 + 55.833\sqrt{2 \times 1005 \times 55.833 + 55.833^2}}{1005}\right)$$

$$335 = 1005\,Ln\,1.39348$$
$$= 1005 \times 2.30258 \times 0.1441 \text{ or}$$
$$335 = 331.8 \text{ or an error of } 335 - 331.8 = 3.2.$$

I now substitute another c for instance, $c = 1010$ and calculate my y accordingly. I find then $y = 335 = 334.26$ or an error in y of $335 - 334.26 = 0.74$ for $c = 1010$.

Then we have $\frac{c - 1005}{c - 1010} = \frac{3.2}{0.74} = 4.324$ or

$c - 1005 = 4.324\,c - 4.324 \times 1010$ or
$c = 1011.504$ which is the correct c.

Using this correct c in the formula

$$H = c\,p, \text{ I get}$$
$$H = 1011.504 \times 3465 = 3{,}504{,}861 \text{ lbs.}$$

Trautwine gives for $^1/_{12}$ deflection

$$H = 1.49 \text{ times total load on, and of span}$$
$$= 1.49 \times 2321740 = 3{,}459{,}392 \text{ lbs.}$$

The result by these 3 different methods is then:

By calculus	$H = 3{,}504{,}861$ lbs.	difference $= 22{,}536$ lbs.
" the parabolic formula	$H = 3{,}482{,}325$ lbs.	
" *Trautwine*	$H = 3{,}459{,}392$ lbs.	difference $= 22{,}933$ lbs.

and as the cables in a suspension bridge are really in practice neither a *parabola* nor a *catenary*, the formula $H = \frac{p\,l^2}{l\,f}$ is good enough.

$V = p\,l = \frac{1}{2}$ total load $= 1{,}160{,}870$ lbs., and using $H = 3{,}482{,}325$ lbs. we have strain on cables at tower =

$$K = \sqrt{H^2 + V^2} = \sqrt{1160870^2 + 3482325^2}$$

$$K = 3670750 \text{ lbs.}$$

Total capacity of cables = *7200* wires, at *1500* lbs. assuming splices not to stand more than *1500* lbs. = *10800000* lbs. or a factor of

$$\frac{10800000}{3670750} = 2.94 \text{ or practically } 3.$$

The suspenders from main cables were ⅞″ in diameter containing 30 wires No. 9, which at 1,500 lbs. gives a capacity of 45,000 lbs. connected to a 1″ o rod at 40,000 lbs. per □″ would be good for 39,000 lbs., or with a factor of 5 would be good for a load of 7,800 lbs. or a factor of 6 in the wire suspender.

The suspenders from the sidewalk cables contained 19 wires attached to ¾″ o rods making wires good for 28,000 lbs. and rod good for 20,000 lbs. or for a factor of 5 in rod, we have a factor of 7 in wire. The suspenders were the strongest part of the structure. If we load the beam till it breaks, we still have a factor of 3.5 in the suspenders, and the suspenders loaded to their full capacity would break three times as many cables as we have. That is to say, cables and floor have about the same capacity, and the suspenders liberal excess.

The wires were bent around a pulley 4½×1″ and wrapped to each other.

The arrangement for passing the cables over the tower is plainly shown on the accompanying plan. The shoes are 6′ square, giving for full load 16 tons per square foot of masonry. The saddle is 3′ 10″ by 3′ 11″ resting on 14 rollers 3′ 8″ long and 2½″ in diameter. The saddle itself consists of 3 portions, the main cable saddle being cast in one piece with the bearing plate, ribs, etc., but the saddles for the sidewalk cable and stay cable are each cast as a box fitting in proper places of the main casting. For some reason or another the stay cable did not pass in the proper saddle, but was in two pieces simply fastened to bolts in the masonry. These bolts were badly rusted, although the entire shoe was put in a niche, and all openings closed with planking. The castings weighed about 8,000 lbs., and were cast by Menzel & Ferguson of Minneapolis.

We now come to a most important feature of the structure: the anchorage, and I will give you what we found as far as we went in removing the anchor piers. My information of the anchor shoes, I got from the patterns of the castings. These patterns are still in the possession of Menzel & Ferguson. Looking at the large plan you will see that each of the 7 cables constituting the main cable divides into 2 strands which wind around a casting provided with a suitable groove to receive the wires, and a pin to receive the eye bars. The length of the loop is about 10 feet. The two strands forming the loop have the same dimension till within about 2 feet of the casting where they widen out entering the groove of the casting, but peculiarly enough not in the same manner. The principal feature of the casting is its appliance for adjusting the cables attached to it. The pin of the eye bars travels in a slot and fitting close to the back of the pin is another casting with a flat surface. Between this loose casting (box if you please) and the solid portion of the main casting, wedges

are driven to adjust the cable properly. Although all this iron work had been oiled and well red-leaded, it showed strong traces of corrosion, so at least in this case cement certainly did rust the iron, notwithstanding any other statements to the contrary. From the castings to street grade 2 links were taken out, and I know there are 3 more links under ground. The elevation of the top of the limerock is about 114 and the bottom 105. The rock is practically horizontal so the last link would be vertical. The 2 stay cables which are running a little apart from the rest have no adjustable attachment, which may account for the manner in which they were fastened at the top of the tower previously mentioned. The last link that attaches to the anchor shoe consists of 14 bars, the size of which are respectively 1⅛″, 1⅛″, 1″, 1, 1 5-16″, 1⅝″, 2″, 2 5-16″, 2 5-16″, 2″, 1⅝″, 1 5-16″, 1″, 1″, all 4″ wide. There are therefore in all 83 sectional inches which at 60,000 lbs. per square , inch (this 60,000 lbs. ultimate strength I find recorded in an old newspaper statement by Mr. Griffeth) amounts to 4,980,000 lbs. The capacity of the wires connecting with the first link was 5,400,000, so the difference has evidently been gained by the deflection intimated, and by the supports under each joint. The eyebars connect at the shoe with a 3½″ pin so the bearing area is

$$3\tfrac{1}{2}'' \times 20\tfrac{3}{4}'' = 72{,}625 \ \square'' \text{ or } \frac{4980000}{72{,}625} = 67{,}200 \text{ lbs p. } \square''$$

ultimate or with a factor of 3—22,600 lbs. p. □″. The shoe proper consists of a nest of ribs intersecting each other, 15 one way and 6 the other. The shoe is placed against a loose cast plate which rests against the rock with a layer of sheet lead between. The bearing area is $4.5' \times 5.25' = 23{,}$-

625 □ feet, ultimate pressure = $\frac{4980000}{23{,}625}$ = 210,800 or with the factor of 3 we have 70,266 lbs. = about 35 tons per square foot, which is considerable. The mould was of dry sand with 108 cores. The cores were made of sand mixed with a little flour, and then baked in an oven before being placed in their proper position. The metal consists of

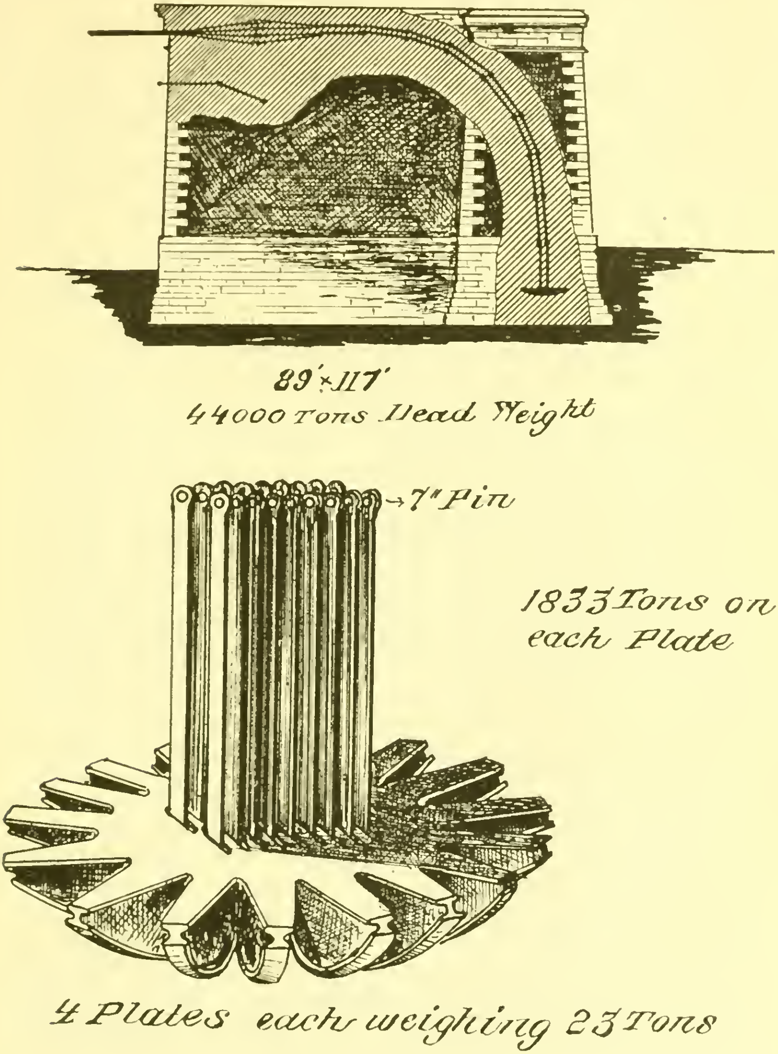
5 parts Lake Superior,
4 parts of hubs of No. 1 car wheels,
1 part of Scotch pig.

The price paid per lb. was 6 cents. The first cast was perfect (it was left two days to cool.)

The second cast was a failure, the rest were O. K. They were the largest castings ever cast in the state at the time, weighing very nearly 10,000 lbs. each. It was also claimed at the time by experts, that these shoes were better proportioned than the anchor shoes of the great Brooklyn bridge. I present you with a sketch of the Brooklyn anchorage without dimensions.

At the time of the construction of these very anchorage castings, there was evidently a lively row. The kickers of the dear public were on deck then as now, but I think that the engineer, Mr. Griffeth, gave them the proper back talk in a manner that might to-day occasionally be applied most appropriately by the engineers of the municipalities of Minneapolis

and St. Paul. With your permission I will read you the prescription. Feb. 13, 1876, in the *Pioneer Press* the following appeared:



BRIDGE ANCHORAGES.

A Confuted Yarn and a Bridge Engineer whose Dander is Rising—The Silent Man Stops Smoking for a Moment and Speaks.

"It beats all how much trouble a good many people are having about bridge matters. After the board of trade had ascertained the fact that

the towers were positively located just exactly in the right spot, it did seem as though the chap who had up to that time insisted that 'I told you so', had lost a situation."

The *Mail* of Friday evening, however, made a discovery in regard to the anchorages as follows:

"And now it is confidentially asserted by knowing ones that the anchorage plates for the suspension bridge are going to weigh 3 tons more than was at first estimated or was really intended. It is claimed that the cast will thus be nearly doubled, and that impracticability on the part of the engineer in charge prevented his being able to make a correct estimate from the pattern. Additional work on the irons will also become necessary. Let us have light."

The Press reporter called on Mr. Griffeth and asked for the light which he got. Mr. Griffeth removed *that pipe* and with a face filled with determination and an occasional trip hammer blow on his drafting table remarked "I will learn these everlasting grumblers something before I am done with it. I know how to build a bridge and they dont. I have been employed to build this bridge and I propose to build it. I sha'n't allow the howlers to build it for me. If Ole Bull was employed to come here and give a concert he would give the concert and he would play first violin even if some blacksmith should desire to play first and have Ole play second fiddle. A man who can't tune a fiddle certainly is not competent to play the instrument. I tell you these men don't know who they are talking to (tremendous thump on the table) but they will find out before I am through with them. Bridge building has been my business for 25 years and I have never yet made a failure. Your city now has a little bridge I built for them 21 years ago. It stands to-day under much greater strain than it was ever intended to sustain, notwithstanding its age, and speaks for itself.

"I have always been treated courteously wherever I have been engaged until my recent advent in Minneapolis. I don't propose to stand this abuse much longer. I can obtain first-class references from the best authorities known to my profession in New York, and I don't propose to allow these grumblers to trifle with me and my reputation any farther. My reputation is my stock in trade and I propose to build for Minneapolis as good a bridge as I know how or none at all. This petty interference, if I longer submit to it, will ruin me and the bridge too. I am under no obligations to manufacturers or parties wishing to furnish material nor do I propose to be. It is to my own and the city's interest that I occupy this independent position and I propose to fight it out on this line. My sole aim has been, and still is, to build for Minneapolis such a bridge as when completed will not detract from my professional reputation and will be of lasting value and benefit to the city."

Engineer Griffeth then replaced that pipe of peace and remarked in reference to the anchor plates that there had been no mistake and that when cast they would weigh about 4 tons each. The plates are estimated to stand a breaking strain of 2340 tons each.

At the time Mr. Griffeth was constructing this bridge he made a report

to the City Council on the condition of the old bridge, stating that, due to the manner in which the roadway had been repaired, probably by piling new floor plank on top of the old ones, repeatedly, the structure was only good for a live load of 21 tons, keeping within a factor of safety of 3.

I have also found records of tests of two coils of wire, made by Mr. Griffeth. One coil broke at 1810.78 lbs. and one at 1864.86 lbs.

Mr. Griffeth said, "The wire shows great tensile strength but splits easily and I must use a different kind of splice from which I intended." He recommended to accept the wire. It was delivered by Roebling of Trenton. The No. 9 wire, (hard drawn charcoal wire), cost 5¾ cents per pound, and the wrapping wire (annealed) cost 8 cents per pound. The city to pay the freight.

Mr. Griffeth also recommended that the cables be erected in the months from June to October.

The towers cost	$41,000
Anchorages	20,500
Wires	30,000
Erection	27,000
Engineer	7,750
Drawings for patterns, etc	1,250

Making, with the work on approaches etc., the total cost recorded May, 1877, about $199,000. The total cost charged up to the Suspension Bridge at the time of removal was $223,000. This extra sum of $24,000 includes widening of sidewalks, some $4,000, and repairs and maintenance.

Arthur McMullen & Co. disposed of the metal as follows:—

To Minn. Scrap Iron Co.	86905 lbs.	cast iron	@ $11.20 ₶ ton		$ 486.67
" Nat. Forge Iron W'ks.	78620 "	wrt. "	" 20.50	"	788.16
" Trenton Iron Works	373000 "	good wire "	30.00	"	5595.00
" Different parties	7072 "	" "	" 40.00	"	121.44
" " "	65510 "	scrap "			381.00
Total,	611107 lbs.				$7372.27

Assuming that the taking down of anchor plates and iron inside is paid for by value of stone in said piers we have

Cost to contractor taking down superstructure	$1497.60
Cost of taking down and storing 1300 yds. masonry	1400.00
Total	$2897.60
Actual cost of masonry in steel arch new half I estimate at	8000.00
Total expense to contractor	$10897.60

The contractor received from the city of Minneapolis:

Cash	$ 4000.00
From sale of iron	7372.27
Assuming that the contractor can dispose of 1000 yds. of stone at $2.00	2000.00

100 yds. of granite at $10.00	1000.00
Total receipts	14372.27
Total expense	10897.60
Profit	$3474.67

This is certainly not much considering the magnitude of the work, and that the contractor must wait to dispose of the stone.

All that is left of the once so proud structure, the suspension bridge of Minneapolis, are the anchor shoes down in the ground, and it may be some future generation unearthing them will consider them great curiosities and wonder what they may have been.

In criticising or discussing this paper, I beg you will consider that not one scrap of drawings, plans or engineering data, whatsoever, was on hand in the city engineer's office of Minneapolis, as Mr. Griffeth carried everything away, and that the data were never gathered with the intention of entertaining the body of engineers I have before me.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JUNE 17, 1891.—A regular meeting was held at the American House, Boston, at 19:45 o'clock. President Stearns in the chair; twenty-three members and five visitors present.

The record of the last meeting was read and approved.

Messrs. Luther Dean, Edward Lyman, Charles T. Main, Harry J. Morrison, Curtis G. Nevers and Frank E. Sherry, were elected members of the Society.

The amendment to Article 2 of the Constitution, striking out at the end of the third clause, the words "and shall not be entitled to vote" was adopted by a vote of 15 in the affirmative and none in the negative.

The Secretary read letters from James B. Francis and Samuel Nott accepting their elections as honorary members.

The Secretary read a communication from the Committee on International Engineering Congress and Engineering Headquarters, World's Columbian Exposition, 1893, enclosing a copy of proceedings of the meeting of May 15, 1891.

The communication was referred to the Board of Government to take such action as seemed desirable and to assure the committee that the Society is in sympathy with the movement.

The Secretary was directed to convey the thanks of the Society to the Merrimack Manufacturing Company and the Lowell Manufacturing Company for courtesies shown the members on the occasion of the visit to Lowell.

The President then introduced Mr. Allen Hazen, Chemist of the State Board of Health, who read a very interesting paper on the Chemical Precipitation of Sewage. The paper was discussed by President Stearns and Messrs. FitzGerald, F. P. Johnson, L. J. Johnson, Adams and others.

Adjourned. S. E. TINKHAM, Secretary.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

JUNE 12TH, 1891.—Club met in the Library Reading Room adjoining the Club Rooms at 8 o'clock, President Gobeille in the chair and about sixty members and visitors present.

The minutes of the last meeting were read and approved. The President appointed Prof. C. S. Howe and Mr. Thos. D. West as tellers to canvass the ballots for election of members. Mr. E. P. Roberts moved that a committee of five be appointed to make arrangements for the annual picnic of the Club. An amendment was offered making the number seven. This was accepted by Mr. Roberts. The motion as amended, instructing the President to appoint a committee of seven members to arrange for the annual picnic of the Club was then put and carried unanimously. The President announced that he would appoint the committee later in the evening. The President reported that a certificate of incorporation had been received and that the Club was now duly incorporated under the laws of Ohio.

Mr. Walter Miller then read the first paper of the evening entitled "Steam Stearing Gear for Lake Vessels," and illustrated with drawings the mechanism by which the greatest accuracy is obtained in turning the rudder any desired number of degrees. This was followed by a short discussion by Messrs. Palmer, Miller,

Brown and others as to the practicability of applying the same or a similar arrangement to cranes and other hoisting machinery.

Mr. E. P. Roberts then read an excellent paper entitled "Considerations Governing the Choice of a Dynamo," in which the good points that should be looked for were fully explained.

Mr. F. C. Osborn then read an interesting account of the recent convention of the American Society of Civil Engineers at Lookout Mountain. A brief discussion and explanation of the different railroads up the mountain followed. The tellers reported that Mr. John B. Weddell had been elected corresponding member The President then announced the following picnic committee: Mr. N. P. Bowler, Chairman, and Messrs. C. P. Leland, J. L. Culley, W. L. Otis, A. Mordecai, F. A. Coburn and G. W. Vaughan.

The President then invited all present into the Club Rooms where an excellent collation had been prepared. After about an hour had been spent in a very pleasant and informal manner the Club adjourned.

A. H. PORTER, Secretary.

JULY 14TH, 1891.—The regular monthly meeting of the Club was held in its rooms in Case Building at 8 o'clock, President Gobeille in the chair, 32 members and several visitors present. The Secretary being absent Mr. Wm. T. Blunt was elected temporary Secretary.

The minutes of the preceding meeting June 12th were read and approved.

Applications for active membership were read from Perry L. Hobbs and Henry A. Barren.

The report of the Club's delegate to the General Committee of Engineering Societies, Columbian Exposition as printed and distributed was taken up and after some discussion the following resolution by Mr. J. L. Culley, was unanimously adopted:

Resolved, That this Club heartily endorses the action of the General Committee of Engineering Societies, Columbian Exposition, so far as the work has progressed, and that we are in full sympathy with the work as set forth in the report of our representative.

The report of the Picnic Committee was presented by the Chairman, Mr. N. P. Bowler. showing receipts of $78.00 and expenditures of $58.40. The balance of $19.60 together with a contribution from the President, was used to cover expenses of collation served at the meeting of June 12. Report accepted and approved.

It was moved by Mr. Mordecai, seconded by Mr. Leland. that the thanks of the Club be tendered to Mr. A. W. Johnston, Superintendent of the N. Y. C. & St. L. R. R., for his courtesy in providing free transportation facilities to the Club at its Annual Picnic on July 11, 1891. Adopted unanimously and the Secretary directed to transmit the same to Mr. Johnston.

Mr. James Ritchie read a paper describing a design for a built plate girder to span a 60-foot store front and carry the floors above of a heavily loaded building. The depth of the girder is the height of the second story and has openings in the web so that ordinary windows are not interfered with. The main difficulty is the transmission of shear on account of the web being interrupted by the window openings. This is overcome by forming the bottom flange partly of a 42-inch plate securely riveted at the pilasters so that the load concentrated there is transmitted through the rivets and the 42-inch plate as if the latter were the full depth of the web.

In the absence of Mr. E. H. Jones, the Secretary read a paper by that gentleman on the recent Providence meeting of the American Society of Mechanical Engineers. It contained many interesting and instructive points from the papers read at that meeting.

Mr. C. P. Leland read an exceedingly interesting report of the recent picnic at Dover Bay Park. On motion of Mr. Mordecai it was unanimously voted to dispense with the August meeting on account of the hot weather.

Adjourned. WM. T. BLUNT, Temporary Secretary.

ENGINEERS' CLUB OF MINNEAPOLIS.

MAY 8TH, 1891:—The fourth joint meeting of the St. Paul and Minneapolis Clubs, was held at the Public Library Building, May 8th. President Pike of the Minneapolis Club in the chair.

Some reminiscences concerning railroads and railroad tunnels in Wisconsin were given by Mr. Woodman of St. Paul.

There was a short discussion which brought out the fact that the best way of ventilating a long tunnel is to run a train through quickly and follow it up with another.

Adjourned. F. W. CAPPELEN, Secretary.

SPECIAL MEETING—MAY 12TH, 1891:—A special meeting was held at the City Engineer's office at 5 p. m., and Prof. Hoag was elected chairman pro tem.

After some correspondence in reference to the Association Journal had been read, a resolution by Mr. Pardee was passed as follows:

Resolved, that this club subscribe for as many copies of the Journal as there are members of the club, the subscription to begin with the beginning of the present year of said Journal. It was also voted to pay the expenses of President Pike as delegate to the meeting of the committee on Engineering Congress, to be held May 15th at Chicago.

Invitations to the annual convention A. S. C. E., was read and ordered acknowledged. so was the matter pertaining to the "Eads Memorial Fund." Mr. Frank J. Llewellyn was proposed for membership.

Adjourned. F. W. CAPPELEN, Secretary.

JUNE 4TH, 1891:—A regular meeting was held at the Public Library, President Pike in the chair.

Engineering News was ordered continued. The action of the Executive Committee on International Engineering Congress and Engineering Headquarters, was approved.

It was also voted that the Treasurer be instructed to forward to the same committee, one ($1.00) dollar per member of the Minneapolis Club.

Mr. Frank J. Llewellyn was elected a member.

The next regular meeting was ordered held in September. Mr. O. Hoff then spoke upon Bridge Erection, calling attention to the fact by not duly considering the matter of erection, very often details were so designed, as to cost a great deal of money in putting the structure up in the field.

He claimed that all couplings should have plenty of play, and of course field riveting be reduced to a minimum.

It pays to waste iron in designing details by the saving on easy and quick erection. Temporary structures for erection, should be figured with factors of safety from three (3) to four (4). New manilla rope with factor of four old ropes with five (5).

Mr. Hoff then mentioned a traveler he is using at present to erect the belt line bridge in this city. The traveler has a reach of ninety (90) feet so as to erect a sixty (60) foot span and a thirty (30) foot tower before moving on.

Total weight of traveler seventy-five thousand (75,000) pounds.

— Cost, one thousand and fifty ($1,050.00) dollars. A counter weight of thirteen thousand four hundred (13,400) pounds was necessary and was furnished by engine and boiler, weighing about twenty (20) tons in working order.

Adjourned. F. W. CAPPELEN, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES
ORGANIZED 1881.

Vol. X. September, 1891. No. 9.

METHOD USED TO DETERMINE THE BEST CAPACITY TO GIVE TO BASIN NO. 5, BOSTON WATER WORKS.

BY DESMOND FITZGERALD, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Report of Remarks made at meeting, May 20, 1891].

The proper size for a storage reservoir on a given water-shed is often difficult to determine.

The following study was made of the subject when the question arose in connection with the building of Basin No. 5, on Indian Brook, in the Sudbury River water-shed.

There are three important factors to observe:

1. The area of the water-shed.
2. The topography of the site.
3. The cost.

In all the computations for Basin 5 the area of the water-shed was taken at 5.9 square miles. The topography indicated that there were three important grade lines which it was desirable to investigate. These were 290, 295 and 300 feet above datum. They flowed respectively 185, 235 and 570 acres and the relative capacities of the storage reservoirs built at these three levels were found to be 1,259,711,250 gallons, 1,603,000,000 gallons and 2,224,000,000 gallons. It is thought by many engineers that eleven inches of water collected in the course of a very dry year is a conservative assumption, but as will be seen later, this is too large a figure when gauged by droughts which have actually occurred within the last few years.

On the basis, however, of eleven inches collected and with the usual deductions for water surfaces the Indian brook would yield 2,906,745 gallons daily. To equalize this flow requires, say, 348,000,000 gallons storage or 120 days supply. It is evident that all storage above this amount can,

after being divided by 365 days, be added to the daily yield of the stream. In the case of the 290 flow line this gives 2,495,600 gallons daily to add to 2,906,745, making 5,402,345 gallons and the same treatment pursued with the other two flow lines gives 6,342,862 and 7,860,369 gallons per day respectively.

The next step was to put these three basins through a severer ordeal. An accurate record has been kept for a number of years on the Sudbury river water-shed, of the actual monthly collections per square mile. A period was selected embracing two years of maximum drought, 1881 and 1883. This period extended from 1878 to 1884 inclusive. The basins were supposed to be full in 1878 and, after crediting the stream for what it would have yielded monthly, it was found that the greatest amount which could be drawn from the 290 basin was only 4,484,000 gallons daily, from the 295 basin only 4,691,559 gallons and from the 300 basin but 4,718,680 gallons daily.

This is the best actual measure that we have of the relative values of these reservoirs. It is well to consider that there should be at all times at least one month's supply of water on hand even after a basin is supposed to be exhausted, and on this basis the above figures would be still farther reduced in the case of the 290 basin to 4,442,534 gallons, daily supply. From the point of view of actual experience it will be seen that there is practically no difference in the values of the basin with 295 and 300 flow lines.

The cost, exclusive of land damages, was estimated at $650,302 for the 290 basin, $742,521 for the 295 and $1,082,697 for the 300 basin. The cost per million gallons on the basis of one dry year, with eleven inches collection, was found to be $13.19, $12.83 and $15.09 for the 290, 295 and 300 basins respectively. On the basis of the delivery of water during the period from 1878 to 1884 the cost per million gallons was found to be $15.89, $17.34 and $25.14. Taking into account land damages and all expenses, it is probable that the basin with the 300 grade flow line would cost almost double that with a 290 flow line and would prove but of little more actual value for the purpose of delivering water during a protracted season of drought.

BOSTON WATER WORKS.

DATA USED TO DETERMINE FLOW LINE OF INDIAN BROOK RESERVOIR.

WATERSHED 5.9 SQUARE MILES.	GRADE 290.	GRADE 295.	GRADE 300.
Flowage area	185 Acres.	235 Acres.	570 Acres.
Capacity in gallons	1,279,711,250	1,603,000,000	2,224 000,000
Daily yield in gallons one dry year with 11 inches collected	5,402,345	6,342,862	7,860,369
Daily yield in gallons from 1878 to 1884	4,484,000	4,691,559	4,718,680
Cost of reservoirs	$650,302	$742,521	$1,082,697
Cost per million gallons delivered, one dry year	$13.19	$12.83	$15.09
Cost per million gallons delivered, 1878-1884	$15.89	$17.34	$25.14

I have said nothing about the questions of raising of roads, shallow flowage, etc. These must be studied for each particular case, but I have given you the general outlines of the investigation and they are those which can be used elsewhere on other water-sheds.

RECENT ADVANCEMENT IN ELECTRICAL ENGINEERING.

By James Ritchie, Member Civil Engineers' Club of Cleveland.

[Read May 12, 1891.]

The advancement of electrical engineering is a subject in which all engineers, both civil and mechanical, have taken great interest, and the study of this branch of engineering is becoming each year more necessary and important. The writer does not claim to be an electrical engineer, but has taken much interest in the development of this branch of engineering, and will describe, to some slight extent, a few of the recent improvements, to which his attention has been called.

At a recent meeting of the American Institute of Electrical Engineers, Mr. N. D. Hodges described a method of protecting a building against lightning, which may not be familiar to us all, and I therefore repeat it here. He argues that we must use the electrical energy of the lightning by some means, instead of attempting to conduct it away, and he employs a thin band of copper for this purpose. The copper is tacked to the outside of the wall of the building and extends from the ridge pole to the foundations, and is so light that the discharge of lightning destroys the band completely, and does so without injury to the building. He claims that he can protect a building between two parallel planes, one of which passes through the upper, and one through the lower end of the conductor. He has found no case of damage happening between these planes, when the conductor has been destroyed by lightning.

An electric type-writer has been invented, by which the operator at one place can transmit his manuscripts hundreds of miles. It is said that the ordinary type-writer characteristics appear on the transmitted copy.

The electric current is used in Italy to purify wine, and to render it less acid.

Two Germans have each invented a process by which the filaments of the incandescent lights can be preserved from deterioration. One is by depositing chromium upon the filament, either chemically or by electrolysis. The claim is that the melting point of chromium is so high, as to resist the action of the electric current and increase the life of the filament. The second method is to deposit nitrides of silicon or boron upon the surface of the filaments. This is done by heating the filaments to high temperature, in an atmosphere of volatile compounds of silicon or boron, and volatile compounds of nitrogen.

A French engineer has discovered a method of repairing broken filaments economically, so that the bulbs can be used again. He makes a hole in the bulb, carefully takes out the broken filament excepting a small piece, which is left attached to the platinum supports. The bulb is then filled with a hydro-carbon liquid, and a new filament inserted, with its ends just touching the piece of old filament. An electric current is then turned on, which decomposes the liquid; the hydrogen liberated, rises through the bulb and the carbon is deposited, cementing the new and old filaments together. The bulb is then cleaned, exhausted of air, and sealed ready for use.

The reduction of aluminum from its oxide by means of the electric current, is one of the greatest results in the way of electrolysis. The metal, which was only recently a comparative myth, is now produced in large quantities, and is used in the manufacture of many articles, both useful and ornamental. Experiments are being made, with reference to its use in the steel plating of vessels, a small quantity of aluminum in the steel, rendering the latter more uniform and more ductile, with a higher ultimate strength.

The *Electrical World* of May 9, states that experiments are to be made with an electric motor to replace steam, on the short branches of the Concord & Montreal R. R. The motor used will probably be that designed by Mr. J. F. Shawhan of Detroit.

In the same issue is a notice of a device for signaling, by means of flashes of light from electric lamps. This may be used upon railroads, by running a special wire, and attaching at any telegraph pole, or at every pole an incandescent light, by means of which, and the device mentioned, signals can be given at any point between or at stations.

An apparatus has recently been tested in Boston, which, if successful, will render safe the ends of broken trolley wires. It is described as a frame made like a parallelogram, between the sides of which is a spiral spring operating a contact bar. Insulated wires in the sides of the frame carry the current to the contact piece. The strain of the trolley wire, attached to the contact bar, holds the latter in contact, and, should the trolley wire break, the force of the spring releases the contact bar, and all of the wire beyond the frame, is dead.

Electric Railroads and their improvements, are before us everywhere. They seem to satisfactorily solve the problem of rapid transit, as they can be built and equipped at much less cost than cable roads. The cost of operating electric and cable roads is about the same, and it thus appears that for anything less than remarkably heavy traffic, the electric road is the most advantageous, and will pay the best interest on the money invested.

DISCUSSION.

MR. WARNER:—I would like to ask a question in regard to the practicability of using electric and cable cars. It has been shown that where the traffic is very heavy the business is more readily handled by the cable cars as the machinery is for the most part under ground and the weight of the car is not as great as that of the electric motor, while on the other hand the electric car must have on it very heavy and complicated machinery which requires a certain amount of power to carry and operate.

However, while the cable cars are dependent for motive power only upon the cable, having no machinery to carry, there is still an objection, that the construction and operation of the cable road is, though more satisfactory in handling heavy traffic, more expensive, while the electric road may be constructed much more cheaply, as the expense of placing the wires overhead is much less than that of placing the cable underneath, even though the additional cost of the equipment of the cars with motors over the cost of the cable car be added to the expense of placing the wires in position. Electric cars can handle light traffic quite as quickly as cable cars, for such traffic electric cars are preferable, but where the traffic is greater the cable cars are of course, better.

MR. ROBERTS:—If the energy that is consumed in conveying two heavy motors the number of miles they traverse each day, could be used in the movement of the car and in carrying the passengers, the electric cars would then be far superior to the cable cars on account of a less expense in equipping the electric road, over the cable road, and the service would be equally as satisfactory as that of the cable road.

MR. WARNER:—Was this band, referred to in Mr. Ritchie's paper, intended as a conductor of electricity, and to protect the house by carrying the electricity into the ground?

MR. BARBER:—The idea of this band as I understand it, is to carry the wire along the side of the house. It evidently carried the whole current with it and left only a dark streak on the side of the house where the wire had been.

MR. PORTER:—I noticed that no mention was made in the paper of an invention of Mr. S. H. Short, a member of this club. We are all familiar with the great amount of noise made by the motors and gearing on all of our street cars. It has been a subject of study by all our companies how to do away with the noise which is so annoying to everybody both on and off the cars.

A number of different motors has been devised, but thus far none of them has proved the success that was hoped for. Mr. Short has lately perfected a motor that does away with all the gearing of every kind, and consequently has done away with all the noise that the gearing makes. As I understand it, the armature of the motor is attached to a hollow sleeve through which the axle of the car wheel passes, and the armature makes only just as many revolutions as the car wheels. These sleeves are supported on an iron frame which is attached to the journal boxes. A spring is placed between the frame and the journal box to arrest the shock.

This spring has but small movement so the sleeve never touches the axle. On the ends of the sleeves are discs, thoroughly insulated from the sleeve, and these discs are attached to the car wheels through heavy stiff spiral springs. These springs afford an easy starting of the car. All the machinery is encased in a sheet iron box, perfectly excluding dust, mud and water.

The field magnets are attached to the body of the car and so made that the car body can be simply raised and the trucks and motor drawn out and replaced by another, in but little more time than it takes to raise and lower the car body.

At present it looks as though Mr. Short had solved the problem which heretofore has baffled so many, and if so he will be entitled to the everlasting gratitude of all those sensitive persons who have been tortured so long a time with the noisy motors.

Mr. Paul is requested by the President to make a few remarks.

MR. PAUL:—There were no electric cars in Cleveland when I lived here excepting one small motor on Cedar with which they were experimenting. I think there has been very great and rapid advancement in this direction, but there is still a great field for labor. Could electric roads be constructed long distances, at a reasonable expense, say from Cleveland to Youngstown, Youngstown to Warren, etc., the possibilities of the electric roads would be almost without limit, but as yet there has been no effort to store electric power, crowned with success.

At present there are only two times in a day at which a person, desiring to stop at local stations, can go in a Westerly direction from this city, as the railroads, by steam, do not run to suit the convenience of the local passengers, while were it practicable to run electric cars, by storage battery, between such local stations, at times during the day to accommodate the local travelers, the expense of transportation, to the public between these small places would be lessened, and the convenience and accommodation to the suburban residents and local travelers would be greatly enhanced.

The immense expense which would attend the stringing of wires between these points, and the almost insurmountable difficulties in obtaining the right of way for such a road, would make this impracticable.

The President requests Mr. Raymond, of the Johnson Co., to tell something of their work in regard to electric welding.

MR. RAYMOND:—We are just now at a point where we are experimenting in this line and I do not know what the company would want me to tell and what to keep to myself.

PRESIDENT:—Would you have any objections to telling us whether you have been successful in welding bars of steel together?

MR. RAYMOND:—We have joined steel rails together by this process successfully.

QUESTION:—Do you regard welding by electricity practicable?

MR. RAYMOND:—I do not think a concern would put several thousand dollars into anything that they did not consider practicable.

QUESTION:—How much power does it take to weld a street railroad girder rail?

MR. RAYMOND:—In some cases it would require 90 horse-power, but 50 horse-power would be an average.

QUESTION:—How strong would the welded place be?

MR. RAYMOND:—The welded place would not be as strong as the bar of steel, but putting the bar under a pressure in a horizontal position the bar would bend before the weld would yield.

MR. RITCHIE:—I saw a piece of spring steel welded to bessemer steel and tested, and the bessemer steel yielded but the weld could not be pulled apart.

MR. PALMER:—Dynamos at the present time are of two kinds, one continuous and the other alternating current. One objection to using the alternating current is, that it cannot be used in all cases; for instance, in cases where the same plant is desired to be used for power purposes and also for lighting purposes, the alternating current is impracticable as welding requires a continuous current, therefore in such cases a dynamo giving a continuous current is not only practicable but necessary.

Mr. Warner speaks of Mr. Short's experiment with an attachment under the motor cars for the purpose of doing away with the noise. A plan is now under way in Germany enabling power to be transmitted 100 miles.

MR. ROBERTS:—Mr. Short has a new motor attached to a car and in working order, and I have repeatedly seen him in the car as he was going up and down Belden street. The motor works perfectly and it seems as though it was a success.

MR. BARBER:—The transmission of power is of course one of the most necessary things for electrical power purposes, particularly in the mining fields and in railroad work.

RECENT GREAT DEVELOPMENTS IN THE MANUFACTURE OF IRON AND STEEL PRODUCTS IN THE UNITED STATES. THE FUTURE SITES OF THESE INDUSTRIES.

BY HORACE A. KEEFER, MEMBER, ENGINEERS' CLUB OF KANSAS CITY.

[Read May 11, 1891.]

If there is any one thing more than another in this mortal existence for the average man to be proud of or thankful for it is the fact that we are citizens of the most energetic, successful, and progressive country in the world. History repeats itself in the wonderful achievements and revolutions produced by the people of the United States; from the casting of British tea into the waters of Boston harbor, through the successful and complete changes produced by the Revolutionary War, the several strifes

with Great Britain since, and the most extensive and bitter Civil War known to the world. All of these were marked by some distinctive features and elements of morality and justice, and in each case placed this people in advance of the civilized world, where we trust she is destined to remain. Trusts, syndicates, and combinations may come and even unwise laws may for a time dim the lustre and stem the onward tide, but the great thinking (and when the time is ripe acting) people of this country will tolerate nothing to exist long, that is not in full accord with the liberal and broad ideas that are born and cultivated to the highest degree in every child of the domain. Not only have we the willing hands and thinking minds, but nature has provided us with all the elements and advantages to profitably combine and employ them to an extent equalled nowhere in the world, (so far as the near future is concerned.)

In the development of our iron and steel industries (here-in-after termed iron industries, for tho' steel is fast supplanting iron in nearly all the industrial arts, iron is the prime metal and always will be,) Great Britain has been our only strong competitor and rival. Every devise, strategic, sympathetic, diplomatic, and even threatening, were resorted to control and restrict the sure and steady advance of these industries in this country, with the most dismal failures. In the fall of 1889 I read before this Society at a field meeting, a paper "On the early development of iron and steel in all countries," tracing it down from the Biblical times to its firm establishment in this country, about the beginning of the present century in New York, New Jersey and Pennsylvania: my present purpose is not to trace these developments which have been of sure and steady growth, (subject like all other industries to many reverses) but to take the status of affairs as found in 1860 and show the wonderful progress since then, to clearly represent this, I have prepared a table showing in periods of 5 years

THE PRODUCTS OF PIG IRON IN GREAT BRITAIN AND UNITED STATES.

YEAR.	1860.	1865.	1870.	1875.	1880.	1885.	1890.
Great Britain..	4,200,000	5,400,000	6,500,000	7,000,000	8,800,000	8,300,000	9,000,000
United States.	1,000,000	1,000,000	1,800,000	2.200.000	4.000.000	4,500,000	10,400,000

The Bessemer steel industries for the same period show about a like increase with same fluctuations, except that we took the lead away from Great Britain in 1880 when the products of the two countries ran closely together until 1885 when the United States rapidly pulled away, and at the close of 1890 we made 3,800,000 tons against Great Britain's 2,400,000 tons.

At the breaking out of the Civil War in this country in 1861, we made less than one-fourth as much pig iron as Great Britain nor did we make any advancement in the next five years in which our capital and efforts were diverted in another direction, but as soon as peace was declared the

nation had decided to stand united as one people, the progress in the developments of our iron industries was certain and rapid, so that in 1870 we had in 4 years nearly doubled our products, jumping from 1,000,000 to 1,800,000 tons against Great Britain's 6,500,000 tons.

In 1875 the ratio produced by the two countries still stood about the same, Great Britain making 7,000,000, United States 2,200,000 tons. In 1880 both countries make a great jump, United States about doubling, making 4,000,000 tons, and Great Britain 8,800,000. In 1885 while the United States added a half million tons to her products Great Britain dropped behind a like amount; while in 1890 the banner year for the development of this industry in the United States, the records show the wonderful output in this country of 10,400,000 tons; 1,500,000 tons, more than double that produced in 1885, and about six times as much as in 1870, a gain of 8,600,000 tons in 20 years, or 1,500,000 more than Great Britain developed in 1800 years. (her products for 1890 being 9,000,000 tons, a gain in a decade of only 200,000 tons and about doubling her output in 30 years.)

Can any one examine these figures and for a moment doubt the relative position of these two countries at the close of the next quarter century? It is true the iron trade has suffered greatly at times from dullness, caused as it would seem from over production, and the profile outlining both production and prices is very like that of a traveler crossing a great mountain range. Starting in 1871 from a slight depression and ascending rapidly through 1872 we reach a table-land of considerable height, which is of sufficient area to consume 1872 and 1873. In traversing, we cross this only to find at the other side a deep ravine the bottom of which we cannot see, and to reach which occupies indeed all of 1875 and 1876, we have meanwhile descended to a depth almost on a level with our starting point just five years before; again ascending abruptly we meet no check until 1883; 1884 and 1885 finds us crossing another ravine, but we are very much higher and the ravine is not so deep, so we quickly recover our height on the other bank; finally in 1885 we commence an almost perpendicular ascent uninterrupted except in 1888 we find a short spur on which we take breath and then continue on till the great plain of 1890 is reached, but by no means the summit. Matters were getting very cold for John Bull about '88 as he surveyed us from his hole, but a little above us. He made a spasmodic effort to head us off, but something frightened him (perhaps a polar bear), at all events we were going in opposite directions so rapidly in 1890 we did not have even time enough to pass the compliments usually observed when old friends (?) meet; so we were waited on this past year for the first time, by a distinguished body of English iron manufacturers to see what manner of people we are, and the locomotion used that could not be stopped even to take them aboard. John will get on, and already you may hear the tread of his ponderous feet in Alabama where he is preparing to absorb the most gigantic creature there. We find in depressed times those who would feel it a discourtesy to their judgment if their advice were asked upon a proposition to increase their pro-

ductive capacity. They have no hesitancy in condemning those who have doubled their capacities in even flush times; which bold proceeding has in their opinion created a capacity far in excess of demands. We cannot overestimate the gravity of the situation during the gloomy periods while crossing the divides I have just described, and in whose sloughs many were lost, but in face of these facts and despite the advice of those who shook their heads at rash investments, all the improvements and many more were needed to keep pace with the tremendous increase when the tide turned. It looks now as though we might have to bridge another ravine. In the meanwhile what will be done and what are we justified in doing? Statistics show that the United States alone consume annually about one-seventh ton of pig iron per capita, now assuming that in the next quarter of a century our population will be 100,000,000 their wants alone will require 15,000,000 tons annually.

Add to this our export trade that must materially increase from now on, the impetus given to the tin plate industry which in 1889 alone represented an importation of at least 500,000 tons pig iron (or just half of what the whole country produced in 1865) the increased demands for heavy armor and ordnance (plates having recently been made ten and twelve inches in thickness, 6 by 8 ft. in dimensions) metallic ties for permanent road beds, conduits and heavier rails for tramways, steel cars, and the many new uses for which iron is being substituted for other materials, it seems safe to place the probable wants for 1915 at 20,000,000 tons, double the present output. Is it not safe to assert that G. B., while she has probably not attained the highest point in the output of these products, cannot from her limited fields and over-burdened laborers, materially increase or cheapen? (The average cost as collected by Commissioner of Labor, Mr. Wright, from 26 furnaces in this country recently, gives $10.75 for the southern districts and $13.94 for northern districts of the U. S., as against $10.50 for G. B. and this difference is entirely represented, so far as G. B. is concerned, by labor charges). Now let us see what we have to supply present wants and to take care of the anticipated future (for if we don't consume annually the one-seventh ton per capita we will make it all up by the end of the quarter century). There were in the U. S., May 1st, 1890—

247 coke furnaces with an annual capacity if steadily employed of about	8,897,000 tons.
190 anthracite	3,800,000 tons.
123 charcoal furnaces, annual capacity	1,123,000 tons.
Total if steadily in blast	13,820,000 tons.

At least 25 per cent. of these stacks in the best of times will be, from the many causes contingent upon the operations of a furnace, idle, and I do not think it unreasonable to say 10 per cent. more will be obsolete in the near future, thus cutting down our possible output fully one-third, or about the maximum reached in 1890. Barely enough to supply present home wants.

We must provide for the future. How are we doing it, and where shall these new industries be located? As transportation more than anything else will solve this and the people can (if they will) control transportation, let us see what is being done by the different localities to further their interests. Not many years ago Chicago was much ridiculed by Penna. Iron Masters for assuming to enter the field in competition with them, later Alabama. What have these people overcome? Chicago receives all her ores many miles from her doors and ships coke from Penna. Alabama makes her own coke and ships her iron into Penna., and is capable of about one-eighth the entire output of this country, and has only just compelled one of the oldest iron producing districts in Ohio to blow out, until the railroads make concessions which will be more equitable, while Penna. imports much ore and ships great quantities through or by Chicago. During 1890, of a total product of ingots made in the U. S., Penna. made 2,515,000 tons and Illinois 848,751 tons, leaving for all the other states 759,360 tons, and while the output for 1890 was phenomenal as to the general trade there was a noted slack demand for steel rails, which largely draw their raw material from the lake regions. If this does not speak loud enough for transportation and energy I will be unable to convince you.

Mr. Edward Atkinson, of Boston, has recently made a prophesy in his publication, "The future Situs of the Principal Iron Products of the World," in which he says, "One may not venture yet to name the specific place or places. The survival of the fittest among the many enterpris e now claiming public attention will soon determine it in the emulation between the North, the South and the West. Suffice it if one should stand apon the highest peak among the Great Smoky mountains in the heart of the Southern Appalachian chain and could bring within his vision all that would come within a radius of 75 to 100 miles, he might be able to establish the centre of iron and steel production, which would not be very far away from what has been called the centre of gravity of the population of the country. If he could bring within his vision the whole configuration of the area included within a circle of 150 miles in diameter, centering on the Great Smoky mountains, he might trace the lines made by the erosion of the rivers and the gaps in the ranges on which the rails may be laid to the northwest at the southern border of Ohio, and to the southwest on the way toward the Atlantic ports of South Carolina, over which the metal produced at the possible future center of the iron production of this country may be distributed on the easiest grades either for domestic consumption or for the supply of foreign markets." Mr. John Birkinbine, Pres't. of the American Institute of Mining Engineers, in a lecture before the Franklin Institute of Philadelphia, has criticised these remarks as follows:—

The region referred to by Mr. Atkinson is known to abound in minerals suitable for conversion into pig iron, and its stores of hidden wealth are probably much greater than is now recognized, but if American pig iron producers could be carried to the peak of the mountain referred to

and be shown all the wealth of the little world of from 40,000 to 80,000 square miles area, even this will hardly tempt them to believe as far as the United States is concerned the prophecy which the text of the paper indicates was made as much to formulate an argument against the present customs duties as to determine the situs. To agree with Mr. Atkinson we must assume that the developments of the ores of the Eastern and Middle States have reached their maximum, that the great coal areas of Pennsylvania, Ohio, Indiana, and Illinois are to see comparatively little future extension in mining operations for metallurgical uses; that the wonderful supply of iron ores of Michigan, Wisconsin, and Minnesota, whose output in 1890 amounted to 8,143,146 gross tons, are to make but little advance in utilization; that the ores of Southern Missouri, Arkansas and Texas and the excellent coal beds near the border of Indian Territory, if developed, are not to be assembled in quantity sufficient for large productive industry. In addition we must make no allowance for the exploitation of the excellent ore deposits of Wyoming, which are distant from Chicago less than 50 per cent. further than the localities from which the present ore supply for furnaces near that city is obtained. We must give Colorado small margin for augmenting its iron industry, and must omit serious consideration of utilizing the known minerals of Utah, and we must also leave out of our calculation the possibility of the Pacific States employing their recognized mineral resources on a liberal scale.

To accept Mr. Atkinson's situs we must dismiss the illusion that the market is a most potent factor for an iron industry, an illusion that has caused capital to embark in iron production and manufacture at points like Chicago, where none of the raw materials are indigenous, but where they can be assembled advantageously and where unexcelled market facilities are offered.

If we endorse his conclusion as correct, we must question the business forsight of the Pennsylvania Steel Works erecting large works near Baltimore, to which fuel must be carried over 200 miles, and ores brought from Cuba, and also doubt the wisdom of the addition to the iron and steel works at or near Pittsburg and Chicago. In fact we must assume that those most intimately associated with the pig iron industry have given no thought to the future. Mr. Atkinson apparently treats of the future solely in the light of the past, without making due allowance for possible and probable advances in mining, preparing and transporting fuel, ores, &c., &c., in modifying present practices or processes, or in utilizing waste materials. The next quarter of a century may show improvements which would surprise us as much as the output of some of our mines or furnaces or the present use of compressed air, electric light and gaseous fuel would have done 20 years ago.

The iron industries of Pennsylvania are here to stay; the ores of New York and the Lake Superior region will continue to be in great demand.

The South and the West will add to their industries; Canada, too, will develope her resources; iron production and manufacture will extend beyond the Continental divide and follow the tide of population rather than

congregate in a limited area of mineral development. In this the localities indicated by Mr. Atkinson will share, and possibly share liberally: but allowing for a considerable export trade, it is probable that the future situs of iron production in the U. S. will be considerably removed from the point indicated and that of the world still further from the highest peak of the Great Smoky Mountain." Mr. Birkinbine from the nature of his work in the last twenty years and the opportunities which it has afforded him is placed in a position to determine the values of the great coal and iron deposits of this country perhaps more accurately and conclusively than any one else. His statements, therefore are entitled to the highest credit. Let us follow up his remarks "that iron production and manufacture will extend beyond the Continental divide and follow the tide of population rather than congregate in a limited area of development." In a bulletin recently issued by the census office giving the distribution of population in U. S. in 1890, 1880 and 1870, upon a drainage basis, the table shows that 96 per cent of the inhabitants live in the country drained to the Atlantic Ocean; more than one-half live in the region drained to the gulf of Mexico and about 44 per cent of the entire population are congregated in the drainage area of the Mississippi River; that the proportion living within the region drained to the Atlantic is steadily diminishing, while of this region the part drained to the Gulf of Mexico is becoming relatively more populous as is the case in a more marked degree in the great basin and the region drained to the Pacific. This increase in favor of the West will be more marked in the future, and already the great people of the West as well as shrewd and thinking men of the East have begun to move.

The Washburn-Moen Co. have just purchased 60 acres of land in South Chicago, to which they will at an early day, remove their plant or erect another and independent one of large proportions. The Illinois Steel Co. have unanimously decided to increase their capital stock from $25,000,000 to $50,000,000, (this company received during 1890, 3,642,660 tons of raw material, of which *only* 755,183 tons were transported by water; they shipped 923,765 tons finished product and paid in wages and salaries to 9,643 men $6,863,416.)

The Colorado Iron Works have lately been incorporated with a capital of $1,000,000, and the Colorado Iron and Coal Co. have decided to largely increase their present facilities. In Texas, at New Birmingham, Taylor, the Llano district and at Jefferson, new stacks have gone up. The Lone Star Iron Co., at the last named point have authorized an expenditure of $1,000,000 for a steel works in addition to their furnace. The American Iron-Steel Co., Cle-Elum, Washington, will soon break ground for a large plant, in which it is contemplated to at once expend $1,500,000. Ogden and Salt Lake, Utah, are both getting ready to develope the large deposits of ore in their vicinity. California has doubled her output of finished product in a few years, and while there are rich fields being opened in Minnesota and Wisconsin, the South too is awake and is ably represented. In a speech lately made by Mr. A. M. Shook, general man-

ager Southern Iron Co., before a gathering of iron men at Chattanooga, outlining the great ore belt of the South, he says: "Commencing with the Brown ores and the coking coals of Virginia, the magnetic ores of western North Carolina, the coalfields of southwest Virginia, and the fossil or Clinton ores of upper east Tennessee; then coming south and west between the head waters of the Cumberland and Tennessee Rivers, are vast fields of coals and ores, which reach down both sides of Waldens' Ridge, extending on the one side from Murphy, N. C., to Marietta, Ga., and thence down by Anniston to Birmingham, on the other side from Cumberland Gap and Middlesborough, thence down the Cumberland River almost to Paducah, then turning south, extending up the Tennessee River to Sheffield and Florence, thence to Birmingham and below, forming a very large area of country, rich in coal, ores and limestones."

Following up this description Mr. Shook peering with clear foresight into the future shows what his section must do to keep their place in the forward ranks as manufacturers of iron in the following expressive language: "The railroads in this country are the largest factors in the developement of the iron and steel industries, and I must say to the credit of the roads of the South, that the very liberal policy they have adopted, not only as regards the transportation of the raw material to the furnace, but also the transportation of the products to Ohio, and Mississippi points, has done more to foster the developments of the iron industries in the South than everything else combined. Another fact has enabled us to get a cheap product from our furnaces which is this: Most of the furnaces own their own ores and their own coals, and these ores and coals are charged to the furnace at cost, not even a nominal royalty charge is made for the purpose of covering exhaustion, while in the North the reverse is true; the furnaces do not, as a rule,own their own coal and ore mines,and are forced to pay the coal and ore miners not only a profit for mining his coal and ore, but also a royalty in addition, and to this is due the fact that to-day the furnaces in the Mahoning and Shenango Valleys are out of blast.

"This condition of affairs cannot and will not continue.

Connellsville coke can be produced at $1.00 per ton. It is now selling at ovens at $1.76 per ton. Lake ores can be put on the docks at $1.50 to $3.00 per ton; they are selling, and have been selling, at from $4.00 to $7.00 per ton. Transportation companies have been getting from ¾ to 1½ cents per ton per mile for bringing these materials together. They can bring them together for less than ½ cent per ton per mile, and will do so if it becomes necessary to meet Southern competition. When these reductions are made the furnaces in the Mahoning and Shenango Valleys will be able to produce iron at from $1.00 to $3.00 per ton less than they are now producing it, and this will enable them not only to hold their own market, but to meet us at the Ohio River. In view of these facts, is it not true that, if we expect to attain greatness as iron and steel producers, we will have to manipulate our material so as to make a better pig iron, and convert that pig iron into steel or other forms of finished product."

Capital is taking a breathing spell now and when it recovers its breath

and begins to look around for new fields, will it not recognize the rich and overlooked deposits of iron and coal in Missouri, Arkansas and Indian Territory, and following up the tide of immigration, and with an energy such as was shown in Illinois and Alabama several years ago, and is now being exerted in Virginia, backed by liberal policies of railroads, (which have been painfully absent in this section,) turn the sleepy hills and hollows into noisy activity. And shall we not, between the Lake, Alabama, Tennessee, Missouri, Arkansas, Texas, Colorado and Utah *ores*; Missouri, Arkansas, and Indian Territory *coals*, with transportation facilities equal to anywhere in the world, before the close of the next quarter century see Kansas City by virtue of its location, commanding easy access to all this raw material (to say nothing of the immense quantities of old materials that must be reworked), and surrounded by a country rapidly increasing in population, close to the centre of the principal manufactories of iron, at least for the great section West of the Mississippi River? Nothing but a persistent inactivity and lethargy of this people will prevent it.

CONSIDERATIONS GOVERNING THE CHOICE OF A DYNAMO.

BY PROF. E. P. ROBERTS, MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read June 9, 1891.]

To select a dynamo, for a given purpose, is quite a different affair from designing one. In the latter case the type of machine is first determined and then the proportions of the electrical details decided by deduction from theory and by experiment. The proportioning of the mechanica parts must be kept in view whilst designing the electrical features, and both mechanical and electrical elements varied until they unite to best subserve the attainment of the object desired:—which is the construction of a dynamo to do the work required with the minimum of first cost and with reliability and economy of operation. A dynamo designer should have, in addition to a knowledge of the laws governing electrical and magnetic circuits, a knowledge of machine design and construction. The knowledge so possessed must be applied to the study of the results following the modification of any feature in the general type and special form chosen. The study of the various losses taking place in a dynamo necessitates an analysis of the same, in order to obtain the value of each loss when the details of the general design are modified. Such losses are friction, Ohmic resistance, self induction, magnetic resistance, magnetic leakage, Foucault currents, hysteresis, etc. After obtaining the above information the dynamo designer will apply his personality—which is partly genius, but mostly the result of varied experience carefully digested —and the result will be a piece of apparatus which will accomplish the

object desired with as much certainty as will a special machine tool designed by an expert in that line.

The purchaser of a dynamo approaches the subject from a very different direction. He desires a dynamo which is, above all, reliable. Secondly, efficient, as regards the ratio of the power generated to that consumed; and, Thirdly, efficient in all the many ways which go to make any machine efficient in every day use, Fourthly, (or firstly, secondly or thirdly, according to circumstances, but more generally according to the wisdom of the purchaser,) cheap. In order to criticise a dynamo it is advisable to analyse it and study each element. In order to do this systematically the following chart is prepared and then a few remarks made under each heading. The chart refers only to points to be studied by a *purchaser*. If a dynamo has 90 per cent. commercial efficiency under a certain load, he does not care what disposition is made of the 10 per cent. lost, provided it is not detrimental to the lasting qualities of the dynamo. It is all the same to him if 2 per cent. be lost in Foucault currents and 3 per cent. in Ohmic resistance and 5 per cent. in friction as it would be if the figures were interchanged, provided lubrication and insulation do not suffer.

DYNAMO.	MECHANICAL DESIGN.	*Strength, Rigidity, Accessibility, Lubrication, Revolutions per minute.*
	CONSTRUCTION.	*Material, Workmanship, Balance, Manufactured to gauge, Insulation.*
	ELECTRICAL DESIGN.	*Commercial efficiency, Operative efficiency, Adaptability to work desired, Heating, Sparking.*

These points will be considered in the following order:

(1) Mechanical design.

(2) Electrical design.

(3) Construction.

These divisions can be advantageously subdivided, but the line of demarkation is not distinct and remarks under one head will sometimes be repeated in part, or referred to, under other divisions.

(1) Considering the dynamo as a mechanism, there present themselves as to its design: (A) The Frame; ((B) The Bearings; (C) The Revolving Portion.

(A) The frame should be rigid, should give ease of access to the commutator and brushes for adjustment and cleaning, and should allow repairs to be made with ease and celerity to such parts of the mechanism as are subjected to the greatest stresses, electrical or mechanical, or to constant wear. The frame should make the center line of the revolving portion as low as practicable, and have a good spread of base.

(B) The bearings should be of ample size, easily replaced and have positive lubrication. Also, arrangements for catching the oil after use should be provided; no oil should creep along the shaft, or be thrown off. Oil, in any other place than the bearings, is not only unsightly and liable to cause fires, but also collects dirt and copper dust from the commutator, causing electrical troubles. Upon the score of economy all oil should be caught and strained and then either mixed with fresh oil and used in the dynamo, or used for shaft or other slow speed bearings.

(C) The revolving portion should be firmly fastened to a rigid shaft, and should not depend merely upon set screws or other form of frictional fastening. The shaft should never bend; since if it does, even to a slight degree, increased friction at the bearings will result. Possibly, also, the revolving portion may hit the stationary parts, or the shaft may break after running a short time. The fewer the revolutions per minute the larger the pulley upon the dynamo, and this is important, particularly when the dynamo is driven from shafting, as large pulleys—especially large friction pulleys—are expensive and necessitate considerable space within which to rotate.

(2) Electrical Design.

The main point to be considered, under the head of Electrical Design, by the purchaser of a dynamo, is its "Commercial Efficiency," which is the ratio of the power given out to that absorbed. The power given out is expressed in watts and that absorbed in foot pounds or horse power. Another kind of commercial efficiency must, however, be considered:

First, the commercial efficiency in its limited sense as above used. Next the output per dollar expended (a) in buying the dynamo, (b) in furnishing power, (c) in operating expenses of all kinds, and (d) in reliability. Combining these is obtained what is herein termed the "operative efficiency."

It is very evident that an unreliable dynamo is not practically efficient however well it can be made to perform during testing.

It is, of course, desirable that the dynamo should have a large output per h. p. absorbed, that is, "commercial efficiency," not only when at full load, but under any fraction of the same. It is also desirable that it should have a large output—

Per dollar of first cost.

Per dollar of repairs.

Per dollar of attendance whilst running.

Per dollar of attendance to clean.

Per pound of total weight.

Per square foot of floor space.

Per cubic foot space (in some locations, as on board ship).

The output per h. p. expended at the dynamo pulley to drive the same is a matter easily obtained, to a fair degree of accuracy, without expensive apparatus.

The h. p. absorbed can be measured by a number of devices. Numerous forms of transmission dynamo meters are in use. An excellent one is

the Van Winkle dynamometer. The pulley which transmits power to the dynamo is loose on the shaft and is rotated through the medium of spiral springs, one end of which is fastened to the pulley and the other end to a disc keyed to the shaft. Mechanism is arranged which indicates by a pointer the tension on the spring at any moment. The revolutions per minute being known, the h. p. can be computed. A scale is attached and the h. p. transmitted can be directly read. Some prefer to have the figure indicated not to the actual amount, but one the value of which can be found by reference to a private note book. The apparatus is split throughout, so that it can be readily placed upon any shaft, and bushings can be inserted to fit the shaft.

The Brackett cradle is extensively used, and consists of a platform, upon which the dynamo is placed, said platform being suspended by end frames carrying knife edges resting upon hardened surfaces. The dynamo shaft is adjusted until its axis passes through the line of the knife edges.

The dynamo is so balanced by weights carried on horizontal arms or on the bed of the cradle, that the latter swings easily and freely on the knife edges, and by means of weights vertically above or below the knife edges the center of gravity is adjusted until any desired degree of sensitiveness is obtained, viz.: until any desired change on the counterpoise or the horizontal arm throws the cradle out of balance. The center of gravity must not be raised above the line of support or the cradle will be in unstable equilibrium, i. e., will be top-heavy and will remain tipped to either side. The belt must be off the pulley while adjusting the weight.

When the dynamo is driven the reaction of the armature upon the field tends to rotate the system, and balance is maintained by adjusting the position of the counterpoise on the horizontal arm or by the extension of a spring scale balance attached to it. The continued product of the weight of the counterpoise (or pull on the spring balance,) its horizontal distance from the center line and the revolutions per minute of the dynamo, equals the foot pounds taken by the dynamo.

The number of revolutions per minute may be determined by any one of several devices. A common method is to use a watch and a speed indicator, the point of which is held against the center of the shaft and the speed is determined by noting the number of revolutions indicated on the dial during a minute, or any convenient fraction thereof. This method is rather troublesome, unless two observers are available, one to attend to the indicator and the other to call time. A convenient instrument combines the indicator with a stop watch in such a way that the rotating point operates the registering device only for a certain length of time, so that the revolutions per minute are indicated directly. Another class of instrument is the tachometer, which may either be operated by a belt or may be held against the end of the shaft. In the tachometer, centrifugal force causes a pointer to move along a scale graduated to read revolutions per minute. The greatest sourse of inaccuracy in the use of any of these instruments is the liability to slip. This is minimized, in the case of instruments operated by contact against the end of the shaft, by having

sharp edges on the point or giving it a soft rubber tip. A good method is to use a three edged punch and punch the "center" with the same. The marks thus made hold the point of the counter and do not injure the center. In the use of the tachometer and belt, care should be taken that the belt is tight and that the pulley on the shaft is of the exact size required. When an indicator is not obtainable the speed may be determined approximately by counting the revolutions of engine or shaft and multiplying by the ratio between the diameters of pulleys. The speed of the engine may be counted by letting one hand move with some reciprocating part or allowing some part, such as a setscrew, on the shaft, or crankpin of the engine, to strike the hand at each revo ution while a watch is heldin the free hand.

One make of engine, the Ide, has an indicator of h. p. being developed. It really shows the point of cutoff. The number of revolutions and initial pressure of steam being known, the h. p. is determined and the scale calibrated accordingly. If the friction be deducted, the amount being obtained by friction cards, the h. p. transmitted to the dynamos is closely approximated.

ENERGY DEVELOPED BY THE DYNAMO.

The energy now to be considered is that delivered by the machine to the external circuit. The location and character of the electrical losses in the dynamo need not be taken into account by the station operator, with the exception of the consideration that energy lost in the dynamo is converted into heat and in general the less heating the better will be the "operative" and "commercial" efficiency.

In order to determine the output of the dynamo, it is necessary to measure the difference of potential (P. D.) between its terminals and the current (C) flowing in the external circuit. This is usually accomplished by a voltmeter and an ammeter of the proper range to take the measurements desired. In whatever way the P. D. and C. are determined, their product gives the energy in watts and this divided by 746 gives electrical h. p. Electrical h. p. is the same as the standard mechanical h. p., which is the work done by 33,000 pounds falling one foot per minute, or the equivalent of the same.

In order to determine whether the dynamo will do the character of work desired it is operated at the speed given by the manufacturer (not at some other speed and calculations made therefrom) and the "C." and "P. D." at the terminals measured. The energy developed being absorbed by any form of "R." convenient. A curve showing the C and "generator P. D." at various loads is constructed from data so obtained. If desirable curves are made showing the output at various speeds. These curves are called "*characteristics*" and bear much the same relation to a dynamo that an indicator diagram does to a steam engine.

In some cases it is well to prove the dynamo by "short circuiting" it and sometimes by suddenly "open circuiting" it. Also to test the effect of slight variations in the position of the brushes.

From a financial standpoint the output per dollar expended is evident-

ly of importance, and under the same head can generally be placed, though to a lesser degree, the output per square foot of floor space occupied; and, where height must be considered, the output per cubic foot of space, and sometimes also, per pound of weight. In most station work, however, the weight and height need not be considered as between dynamos of about the same output. A large dynamo is cheaper and occupies less floor space per watt developed than its equivalent of smaller ones.

The allowance for repairs is usually figured as a certain percentage of the first cost, and is determined by experience. This is a very uncertain quantity, but where great care is taken to properly clean the dynamo and keep the same in good condition (such as shellacing impaired insulation, etc.,) and where open and short circuits do not occur on the line when operating, and the lightning arresters act properly, the repairs upon dynamos are usually very small, possibly not 2 per cent. per annum of the cost. In other cases it may reach any imaginable figure.

The output per dollar of attendance to clean is, more or less, the reciprocal of the above. The more cleaning the less repairs. Some dynamos, however, take much longer to clean than others and some can never be thoroughly cleaned. The cleaning of dynamos is quite an expense in a large station and an even larger percentage cost in a small one, as a comparatively expensive man may have to do it at times when otherwise he might be more productively engaged.

The output per dollar of attendance while running varies greatly. With some dynamos and their auxiliary mechanisms, so much attendance is necessary as to be a considerable item in a small station, taking all of one man's time in a medium sized station and the time of more than one man if a large number of dynamos are running. This emphasizes the fact, which no one not an operating manager and superintendent of a station fully realizes, that in choosing a system there are many points to be considered besides commercial efficiency, first cost and electrical output of the character desired and as indicated by the characteristic curve.

The mechanical design should be such that the electrical functions of the different parts may not be destroyed by reason of insufficient rigidity, abrasion, etc. It is well to have the armature wires positively driven by the pressure of parts of the armature frame. When an armature revolves rapidly, the wires, including the binding wires upon armatures using such, stretch and are liable to be more or less displaced unless firmly held. If shaft wires are used passing through the shaft to the collector, special care should be given to ensure a smooth and ample space for placing same in position and that dirt be not allowed to settle about entrance and egress holes. The mechanical design of the commutator includes the matter of proper insulation material between each of the commutator strips and between them and the shaft, the whole being put together in such a way that no piece is liable to work loose.

The electrical design necessitates that there shall not be continuity of the iron of the armature core. The reason for this is that the same force

which tends to produce current in the wire would produce current in the iron and heat it if the electrical circuit be complete. Such currents are called Foucault currents. Armature cores are, therefore, made of iron plates, bands or wire. Plates being used when the active wire is parallel to the shaft, bands when at right angles and wire being applicable to either case.

Heating:—Excessive heat will gradually carbonize the insulations of wires and render them brittle and destroy their insulating properties. A safe temperature should not be exceeded after a three hours' run at full load.

What temperature is safe depends upon what the insulation will stand. In other words, high temperature is only injurious, from the standpoint of reliabiliiy, because the insulation may be deteriorated, and the extent of insulation required is a function of the P. D., which may be increased much above its normal value when the circuit under consideration is suddenly opened, particularly if such consists of many turns about an iron core.

When the windings are of considerable depth the external layers are cooler than the internal. In case of an armature, the external layers will be much cooler when running than soon after stopping, as then the conduction of heat will not take place as rapidly, owing to less cool air coming in contact with the wires, and the temperature of the external wires will become more nearly that of the internal layers.

In any case it is advisable not to have the temperature rise so high that the back of the hand cannot be held agains the wires.

Sparking:—The action of the commutating and collecting devices is, in many respects, a guide to the electrical action of the dynamo. If the dynamo be of the open coil type and designed for high E. M. F., and small current, a spark of considerable length can be run without burning the commutator. Such a spark may be run for a year or more on a machine properly attended to and very little wear be perceptible. In closed coil machines and in all large "quantity" machines, the less spark the better. Many can now be observed in operation with almost no perceptible spark, or even scintillation. If the field and armature are electrically balanced this can be accomplished, but the art of so balancing them is outside the province of a station constructing engineer. Whether the brushes are to remain unmoved and non-sparking for changes of load, or whether automatic or hand movement must necessarily, or advisably, accompany such changes, depends often upon the place where the dynamo is located, and the character of the work desired. In other words, whether constant attendance is necessarily provided for other work than to shift brushes and, therefore, will be always at hand; and whether large percentage variations are liable to occur at any moment and unexpectedly. Generally speaking everything should be automatic, but sometimes government is obtained by such a multiplication of devices and accompanied by so many losses of power, that the advantages are not commensurate with the losses, and particularly with the attention necessarily given to

keeping the automatic devices in order. The cost of time taken for this by an expert may even exceed that of, comparatively, unskilled labor for hand regulation.

The commutator and brushes constitute an important part of the dynamo, since the successful collection of the current depends upon their satisfactory operation. As shown before, the requisite quality of the commutator is that it presents a uniform, smooth and clean surface moving with moderate peripheral speed, against which the brushes may maintain easy but sure contact. Likewise the condition to be met by the brushes and their attendant mechanism is that they maintain sure and continuous contact with the revolving commutator, at the same time being well connected to the stationary conductor. This requires that the brush shall be of some good conducting material or that the holder grasp it as near as practicable to the commutator. The brush or the enclosing holder should have a certain amount of springiness. They should preferably be capable of adjustment while running without opening the circuit. Much ingenuity has been exercised upon the development of satisfactory brushes and holders, and many excellent designs are to be found on different machines on the market.

In a few machines the brushes are made to bear tangentially upon the commutator, but in most cases they bear obliquely. Tangential brushes have only a small surface of contact and are easily kept in order; the principal points to be looked after are to see that the brushes do not get worn through at the line of contact and that they retain their elasticity and certainty of contact.

With the brushes set at an angle the surfaces of contact with the commutator are wider, being usually best when equal to the circumferential width of one commutator bar. The brushes should be filed off square and beveled to the desired angle, then set in the holders, or clamps, so that the beveled surfaces bear evenly upon the commutator; they should then be fastened tightly to that they cannot work loose or change position, and the springs adjusted to the proper tension for securing good contact with the minimum friction. The brushes should be kept clean, so as to make good electrical contact both with the commutator and the holders. The ends should not be allowed to become dirty, rough or ragged and may be cleaned occasionally by washing in benzine. As the brushes wear they gradually change their angle and their position on the commutator and leave the non-sparking point. They should, therefore, be trimmed occasionally and reset. Care must be taken that the brushes touch the commutator at diametrically opposite points and to facilitate resetting, a pair of opposite bars should be marked with a center punch, or chisel mark.

It is desirable, especially for machines giving large quantity of current, that there be two, or more, brushes on a side, both to reduce the resistance by increasing the amount of surface between brush and commutator, and so that the operation of the machine will not be entirely dependent upon the proper working of any one brush. When there is more than one brush on a side they should all be set in a line so as not to cover a wider angle on

the commutator than should be covered by any one brush, unless such separation of brushes is part of the means for regulating the dynamo.

"Carbon brushes" have recently come into quite general use and are popular since they do not require so much attention and care as those of copper. They also reduce that part of the sparking due to the short circuiting of armature coils, when the brushes touch two adjacent commutator bars, since the carbon brushes have more resistance than those of copper. In many cases the carbon brushes simply replace the copper ones and are used in the same holders, but more frequently special holder are used.

When the commutator is in good order and the brushes well set so that there is little sparking, the commutator will acquire a glazed surface and will run for months with no other attention than being occasionally oiled. To reduce the abrasion between commutator and brushes, a certain amount of lubrication is desirable, but this should not be excessive since lubricators, as a rule, are insulators and their presence between the brushes and commutator, except in very small quantity, introduces injurious resistance. A small amount of resistance from this source is less objectionable with high tension machines than with low tension. Too much lubricatoin will prevent the brushes from making good contact and the sparking that follows will char the oil and insulation and cause more or less short circuiting of the commutator. Some makers provide automatic commutator oilers, but for most cases occasional wiping the commutator with a piece of cloth or felt impregnated with oil or vaseline is sufficient. For low tension machines a convenient and satisfactory plan is to put a drop or two of oil on a clean finger, shake off the excess and rub the finger over the commutator. Some of the carbon brushes are partially composed of graphite which furnishes the desirable amount of lubrication. Another plan is to boil the carbons in vaseline, which will serve the same purpose without lessening the conductivity of the brush.

When the surface of the commutator becomes dark and dirty it should be scoured off with fine sand-paper. The commutator should not be allowed to get dry since it then scours and there is more or less cutting of both brush and commutator accompanied with undesirable throwing of copper and carbon dust.

Construction:—This can be suitably examined under the heads of Material, Workmanship, Balance of Rotating Parts, Methods of Manufacture, and Insulation.

Material should be what it is represented to be. There is little danger of an efficient dynamo being lacking under this head, unless, possibly, a flaw be found in the shaft or pulley.

Workmanship is to be judged from the standpoint of a machinist who has a knowledge of the electrical functions of the different parts. An electrical machinist used to dynamo work is needed to find flaws in workmanship.

Balance. It is very important, not only for quiet but for continued running, that the revolving portion should be in good running balance.

If the armature is of the disc pattern on a long shaft, a static balance will give a "running" or dynamic balance. If, however, the armature be of the drum pattern, a system such as is used by the Alliance Company or a machine of the character designed by the writer should be used.

Method of Manufacture (*Gauge or Interchangeable System.*) It seems hardly credible that in these times and in this country any machine made in quantities should not be made to gauge; but sometimes it is a fact that a part of a machine "made to gauge" breaks, and the new part does not, unaccountably perhaps, fit.

Insulation. The insulation of any machine is usually designed with reference to the E. M. F., and for safe running in a dry locality. If dampness or injurious vapors or excessive heat be present, special insulation should be provided. When a dynamo has become wet it can be dried out by means of a current. It is best to obtain such current from an external source as then the P. D. between continuous portions is only that due to the R. and not that generated in such portions when acting as a dynamo. If time is not of importance it can be dried, with more safety, by placing it upon a boiler and having the core of the magnet rest upon the shell or dome. This method will, generally, take two weeks to dry out a deep winding.

If an electrical engineer be employed to examine a dynamo he may not actually write out his opinion under each of the above headings. He will determine the characteristic and h. p. consumed, and many of the other points will be merely considered together under the head of excellent, fair, or poor in electrical or mechanical details, or in both.

An electrical engineer who has not had enough experience to grasp as it were intuitively, the detail features and decide thereon without actual analysis, is very liable to a more or less serious omission and regret it afterwards, unless he proceeds in a systematic manner. In any case system is advisable, and clients will have a better opinion of a report which takes up its subject and deals with it fully and comprehensively than if generalities only be presented and those of the characted of the Delphic oracle. At any rate one object has been attained in preparing the chart and that is to present this evening a topic in.I trust, a convenient form for discussion.

DISCUSSION.

Mr. Barber:—I was very much interested in Mr. Robert's paper especially in regard to carbon brushes. I think the carbon brush in relation to dynamos, very much increases the life of the dynamo. The carbon brush appears not to wear the face of the dynamo nearly so much as the copper brush. One point is, that the carbon brush can be used in a Thomson-Houston combination.

We have had a carbon brush in operation nearly two years and after it had been running six months some of the scratches on the face, which were on when the dynamo was put in operation were worn off, as the sparking was not sufficient to erase them. I do not see why carbon brushes cannot be used. There is a slight deterioration of the edge of the dynamo, but in comparison with the copper brush, it is very slight.

HINTS ON CEMENT TESTING.

[Read before the Engineers' Club of St. Louis, April 15, 1891.]

The object in testing cement is to ascertain in measureable terms the agglutinating power it has among its own particles, or between these and other materials which are to be bound together by it. This may be accomplished by crushing, tensile or shearing strain per unit of cross section. The most usual force applied is a tensile strain. At first tests were made with large masses of the concrete and these tests were made in harmony with the conditions of practical application. In this way the value of the cement or concrete was found in a somewhat crude but eminently practical way. It was not possible however to avoid the many influences known to have an important influence on the setting of cement. The present methods of testing aim at ascertaining the value of cement with small quantities and under conditions which shall eliminate those factors that vitiate comparative results on a larger scale. The practical value of the concrete or the product of such concrete is found by separate experiments having only such practical results in view. The factors that cause variations in the results will be pointed out presently.

In Europe there are several testing stations where cement testing has been reduced to such uniformity that the results there obtained are accepted as authoritative to both consumers and producers. No doubt there is much good cement testing done in this country, but if there is any station that has the confidence of consumer or manufacturer that the Berlin station enjoys, the writer is unaware of it. Enough cement is used in this country to deserve of a testing station that can give authoritative results. This station ought not only to make standard tests, but should also make investigations of great value in practice. Confidence in the investigations and results will have to be earned, and when earned it will rest on merit and it will obtain recognition. Costly breaking machines and ingenious molding apparatus and similar devices will not by themselves elicit recognition. Very crude machines will answer when endowed with a master's brain and handled with skillful hands. A skillful tester ought to produce tests that have much smaller deviations from the average of a series than is found in the generality of tests. He ought to be able to test the same cement at different times and seasons of the year and obtain at each test practically the same result. There ought to be the same certainty in his manipulations and results that there is in those of a skillful chemist.

The following schedule shows the various observations made in the testing of cement at the Berlin station. Eleven series of tests are collected from the records to make plain the great differences in the different cements, and even in the same brand.

SCHEDULE NO. 1.

No.	Brand.	Weight per Liter.	Water Required for Producing Plasticity.	Water Required for Setting on Glass.	Time of Setting.	Rise of Temperature in Setting.	At Test Making the Temperature of Air was	At Test Making the Temperature of Water was	At Test Making Humidity of Air was	Rejected by Sieve of Meshes per sq. in. 32,250	5,800	3,870	2,100	1,160	Neat Cement. Mixed with Water.	Neat Cement. Tensile Strength per sq. C. M. in 7 days.	28 days.	1:3 Normal Sand. Mixed with Water.	1:3 Normal Sand. Tensile Strength per sq. C. M. in 7 days.	28 days.
			per cent.	per cent.	Hrs.					%	%	%	%	%	%			%		
43	A	1.986 1.336	30	26	6	5°C.	21°C.	16°C.	68%	24	4	2	2	0	17	63	66	9.25	22.75	25.9
60	A	1.918 1.287	30	26	3¼	5	18.7	15	74	24	4	1	3	0	16	65	—	9.25	25.4	—
124	A	1.754 1.187	34	26	3–6	2	18	15	64	26	2	1.2	0	0	17.5	51.7	60.7	10	22.7	26.6
27	D	2.088 1.491	31	26	4	1.2	22	16.8	68	36	11.5	5	2.7	5	16	25	39.8	9.5	—	12.13
31	D	2.180 1.600	26	22	9	1.8	23.5	16.8	72	54	19.5	8	5	0	—	—	—	95	—	13.55
9	D	1.956 1.372	31	24	2–4½ min.	1.6	18	15	69	26	2	1.2	0	0	17	51	54	9	17.5	23
105	D	1.972 1.396	32	26	10–35	2.6	18	15.5	70	24	2	0	0	0	17.5	32	37.5	9.75	14	20
28	—	1.720 1.181	38	33	4	1.9	23	16	68	12	0	0	0	0	19.75	36	39	9.5	21	28.5
127	Puzz	1.238 .753	64	52	1–11	3.0	18	15	63	6	0	0	0	0	32	21	26	11.5	16	25
51	H	1.606 1.160	36	29	¾–1¾	4.0	18	15	70	4	0	0	0	0	—	—	—	10	—	27.5
50	H	1.932 1.350	30	25	3	1.1	18	15	72	24	7	4	1.5	0	15.5	33	39	9	12.7	17.9

1 Kilo. sq. C. M. = 14.2227 sq. in.   1 sq. in. = 6.4514 sq. C. M.

The foregoing tests and observations are made in accordance with well defined rules and regulations. All of them have a bearing on the quality and value of the cement. The specific gravity or weight per liter, filled loose and shaken down, is indicative of the degree of calcination, the percentage of lime in the cement, and of the fineness of the grinding. The quantity of water required to produce syrupy consistence varies with the density of the clinker, with the time of the setting of the cement and with its fineness. The rise of temperature during the setting varies with the amount of lime in the cement, with the activity of the cement and with its fineness. The temperature of the air and of the water used in making the tests also have influence in the hardening. The setting activity increases with the rise of temperature. At the freezing point setting is almost if not quite suspended. The fineness of cement is a most important element in determining its value. The observations of fineness are recorded in columns 11 to 15. In considering the observations in columns 3 to 10 we see that fineness is a factor in each observation. It is a leading factor in the balance of the table from columns 16 to 21. As its influence is so universal it merits further consideration. Authoritative experiments and tables 1 can be produced for nearly all that is here stated and this paper will not be burdened with a reproduction of them. It is well known, that, when cement is sifted through a sieve having 30,000 to 40,000 meshes per square inch, there is produced a very fine powder which has, when tested, a much lower tensile strength than the original cement. There is also obtained a fine granular residue which when similarly tested has hardly any tensile strength. In the tests hitherto made this residue was directly moistened and formed into briquets. It thus showed a tensile strength not its own, as the adhering dust did what cementing took place. If the dust is removed from these grains by agitating them in a damp cloth, they will practically have no tensile strength when molded into briquets. If on the other hand these grains are ground fine in a mortar, they will make a cement that is superior to the original cement owing to the fact that the best clinker is most difficult to pulverize. This proves that the cement of commerce consists of cement and an inert material. It shows also that the ordinary tests of pure cement are really only the determinations of concretes of different proportions. It follows that the clinker of the same kiln when ground at several different factories may yield several different qualities of cement. It may follow also that these several different grindings differ more from each other than the full product of each factory: The factory that would grind the coarsest and produce the most intermediate grades from very fine to very coarse would turn out the strongest cement when tested neat. The factory that would grind so that all would pass through a seive of 35,000 holes per square inch might have its product re-shipped to Europe. The reason that coarse cement tests higher than fine is because the clinker is stronger than the cement, and in breaking, the clinker particles break, thus adding their extra strength, or they pull out of their bedding, and thus increase practically the sectional area of the briquet. Coarse cement weighs more

per bushel or liter because it packs more solid, the different sizes filling in all interstices. It also sets slower because the real cement must do its work "open file." It shows less rise of temperature because the energy is spread over a larger area. The matter of fineness counts but little when the sieve has 40 or 80 meshes to the linear inch, but when the sieve (I may say perhaps, if the sieve) separates cement from inert material, then fineness becomes of transcendent importance in standard testing. In practice fineness is not of the same importance, except with those who can draw conclusions from other conclusions. The question suggests itself where does true cement begin. This can be found by carefully conducted experiments. The writer does not fill this place, but elicits conclusions from the experiments of others. If, however, cement is levigated it will be found to consist of grains and flocculent matter. The flocculent matter together with small quantities of the finest grains can be washed away, and the balance retained corresponds in weight very closely with that left on the sieve of 32,250 meshes. Hence a sieve of about 35,000 meshes per square inch would be close to the practical dividing line. The grains retained by the washing process can be examined through a magnifying glass. The clinker looks like basalt. The glossy, white, yellow and green particles are fused matter from the lining ashes, or adulteration designedly added.

The first test of cement in standard testing should be for the percentage that will pass through a sieve of about 35,000 meshes per square inch. *This percentage will represent the real cement. The other tests will not then be subject to the indefinite influence of the want of uniformity in fineness. The percentage of water for setting should be and probably could be always the same, especially in connection with uniformity of temperature of cement and water, both of which should be at 32° F. At this point setting is checked and fineness being the same, the water ought to be and could be about the same. The amount of water used in the present practice is a personal equation which is unsatisfactory, and the more so because violent agitation increases plasticity. This introduces the elements of time and degree. The hardening should take place at 212° F., a temperature which can be readily maintained. Hardening will take place more rapidly and shorter periods will give fuller knowledge. Each series of tests should harden in a definite amount of fresh water. Water be-

*Several years ago the writer tested two brands of cement (a German and an English) with a sieve of 10,000 meshes per square inch. The sieve rejected 10% of the English cement and 1½% of the German. Shortly afterwards the same two cements were tested with a sieve of 32,000 meshes per square inch. With that test both cements were found to pass through the sieve about the same quantity, that is about 56%. The cements were then also again tested with the former sieve with the same results first above stated. This shows that the sieve of 10 000 meshes per square inch may cause the rejection of a cement that contains its proper proportion of the very finest. The difference in this particular between the German and English cement is due to the fact that the Germans screen the coarser particles out of their cement, while the English run their mill stones close together and barrel the produc- without screening.

SCHEDULE NO. 2.

In harmony with what is stated in the foregoing, it is believed unnecessary to make or record all the tests of Schedule No. 1. Schedule No. 2 indicates the columns that may be omitted.

No.	Brand.	Weight per Liter.	Water Required for Producing Plasticity.	Water Required for Setting on Glass.	Time of Setting.	Rise of Temperature in Tetting.	At Test Making the Temperature of Air was	At Test Making the Temperature of Water was	At Test Making Humidity of Air was	Rejected by Sieve of Meshes per sq. in. 32,250	5,800	3,870	2,100	1,160	Neat Cement. Mixed with Water.	Neat Cement. Tensile Strength per sq. C. M. in 7 days.	28 days.	1:3 Normal Sand. Mixed with Water.	1:3 Normal Sand. Tensile Strength per sq. C. M. in 7 days.	28 days.
					Hrs.					%	%	%	%	%	%					
43	A	1.986 1.336			6	5°C.			68%	24						63	66		22.75	25.9
60	A	1.918 1.287			3¼	5			71	24						65	—		25.4	—
124	A	1.754 1.187			3-6	2			64	26						51.7	69.7		22.7	26.6
27	D	2.088 1.491			4	1.2			68	36						25	39.8		—	12.13
31	D	2.180 1.600			9	1.8			72	54						—	—		—	13.55
9	D	1.956 1.372			2-4½ min.	1.6			69	26						51	54		17.5	23
105	D	1.972 1.396			10-35	2.6			70	24						32	37.5		14	20
28	—	1.720 1.181			4	1.9			68	12						36	29		21	28.5
127	Puzz.	1.238 .753			1-11	3.0			63	6						21	26		16	25
21	H	1.606 1.160			¾-1¾	4.0			70	4						—	—		—	27.5
50	H	1.932 1.350			3	1.1			72	24						33	39		12.7	17.9

1 Kilo. sq. C. M. = 14.22275 sq. in. 1 sq. in. = 6.4514 sq. C. M.

comes alkaline when tests are immersed in it, and alkaline water has not the same influence as fresh water in the hardening process. Some of the published results do not seem to have taken into consideration temperature, or the change of water in comparing hardening in flowing water with hardening in the laboratory. By the course outlined above, the foregoing schedule could be abridged and the results obtained would be more indicative of the quality and nature of the cement. From the observations in foregoing schedule the influence of fineness, gravity, time of setting can be traced, but only dimly. For example, the fineness of brand H,No. 51. calls for 6 per cent. more of water than No. 51. But owing to the fact that No. 51 also has much lower gravity than No. 50 we can not tell whether this was all due to fineness or partly to lower degree of calcination. If fineness was the same in both then the gravity and the quickness of its setting would point quite clearly to light burnt cement. Many interesting deductions can be drawn from the figures in .the schedule. We will however, leave tne subject for the present to those who have the opportunities to develop the ideas herein suggested.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF ST. LOUIS.

349TH MEETING, JUNE 3, 1891.—The club met in the club rooms, President Burnet in the chair, and twenty-six members and two visitors present. The minutes of the 348th meeting were read and approved.

The executive committee reported the doings of its 112th and 113th meetings. Mr. G. R. Mann was approved for membership. The result of the ballot election showed that there was a tie vote for J. A. Ockerson and S. Bent Russell for vice-president, while R. E. McMath was unanimously elected librarian.

On motion the election of a vice-president was deferred till the September meeting, when nominations should be made.

Mr. Geo. R. Mann was elected a member of the club.

Col. Meier presented a report of the committee of engineering societies held in Chicago, May 15th.

On motion Col. Meier's report was accepted and the proceedings of the meeting endorsed.

The amendment to the by-laws, Sec. 4, by striking out everything after the word club on the second line was adopted by a two-thirds vote.

Prof. J. B. Johnson was elected a member of the board of managers for the Association of Engineering Societies.

It was moved and carried that a committee of three, including the president, be appointed by the chair to revise the constitution and by-laws. Messrs Burnet, Holman and Crosby were appointed.

On motion the treasurer was instructed to collect the assessment of $1 per member and forward to the treasurer of the General Committee of Engineering Societies.

Dr. Wellington Adams then read the paper of the evening on "The Problem of Mechanically Propelling Road Vehicles."

Dr. Adams gave a brief history of the attempts to solve the problem commencing in 1759, when Dr. Robinson first suggested to Watt the use of steam for propelling carriages upon the common roads. Many have attempted to solve the problem by the use of a variety of forms of motive power, such as compressed air, ammonia gas, carbonic acid generated in confinement, the explosion of coal gas and hydrocarbon vapors and electric motors. While some success attended these experiments the introduction of the steam railroad discouraged further effort.

Dr. Adams undertook to solve the problem by employing a high speed rotary steam engine running at 1000 revolutions per minute, the fuel to be gasoline. The details for the engine and boiler were fully illustrated by drawings. The manner of mounting the propelling mechanism was such that the irregularities of the road would not interfere with the running of the vehicle.

Discussion followed by Messrs. Burnet, Holman, Adams, Flad and Seddon.

The paper for the next meeting, September 23, on "Notes on the Harcuvar Pipe Line," by Frank Nicholson, was then announced.

Adjourned, ARTHUR THACHER, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES
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NOTES ON RAILROADS AND RAILROAD TUNNELS IN WISCONSIN.

[PRESENTED AT A JOINT MEETING OF THE ST. PAUL AND MINNEAPOLIS CLUBS, IN MINNEAPOLIS, MAY 8, 1891, BY MR. WOODMAN, OF ST. PAUL.]

The topographical slope of Wisconsin is from the Northwest to the Southeast, and the Wisconsin river has a fall of nine hundred feet in its descent to the Mississippi river.

Two large valleys of the Wisconsin and Rock rivers, are followed, the one by the Milwaukee and the other by the Northwestern railroad. The elevation of the Rock river valley is about seven hundred and eighty feet and of the Milwaukee road about six hundred feet.

Although the topographical features hardly indicate it, there is one point, forming a circle of twenty miles in diameter, where the head waters of several rivers are found, where six tunnels are located, having a total length of two miles and which were built at a cost of $700,000.

The ridge elevation at this point is about 1300 feet and the contours quite broken. The tunnels are all in the same geological formation, the St. Peter sand rock, which underlies the Trenton lime rock. We have the same formation in this locality. This sand rock consists of pure white sand, possessing very little cohesion and is therefore easily worked.

A peculiar geological feature of Wisconsin is the fact that, following the country down from Northwest to Southeast, we have in view the different formations from the first to the present one. Of twenty-six miles of road at the above mentioned circle, twenty-one miles are on a sixty-six feet grade, which is almost a montainous grade. The difficulty of operating is apparent from the fact that a mogul engine with 18″ x 24″ cylinder can haul only twelve cars.

The Greenfield tunnel, used by the C. M. & St. P. is one-quarter of a

mile long in a very soft portion of the rock. The tunnel had to be timbered and finally it became so unsafe that a new one had to be built forty-five feet from and parallel with the original one. The grade in the new tunnel is only thirty-five feet per mile, which is the maximum grade of this road.

Working one end at a time, the average progress was eight and three-tenths feet for twenty-four hours.

The North Western has three tunnels all running on township lines about six to seven miles apart. The longest, 3,810 feet, was built under the writer's supervision. The West approach was very much broken up. Both ends were worked as well as two shafts, one vertical seventy-five feet deep and one on a slope one-hundred and thirty-five feet long. Considerable trouble was caused by water. The tunnel passed through a regular artesian well. Two shifts were worked each of eleven hours.

The average progress of the three tunnels were in No. 1, 53.7 feet per week; No. 2, 52 feet per week; No. 3, 21.7 feet per week.

A bonus was offered in No. 3 to pay the miners five dollars for every foot made over thirty-three feet per week, and the progress was thus advanced to forty-two feet as against twenty one and seven-tenths feet. The greatest progress in No. 3 was fifty–one feet per week in soft places.

Generally the heading was squared in three rounds. First three foot holes were excavated, then three mean holes and then three top holes. The area of a section was about twelve square yards. The drillers could be heard two hundred and seventy feet distant through the rock. Only hand drills were used. The average taken out in No. 1 was 11.98 yards per foot; No. 2 was 12.64 yards per foot; No. 3 was 11.2 yards per foot. No. 3 was estimated at 11.1 yards per foot, and all three were designed to be of the same dimensions.

The contract price in No. 1 and 3 was four dollars and fifty cents per yard, in No. 2 it was thre dollars and seventy-five cents. There was no reason for these prices except the guess work of the contractors.

No. 3 cost every cent that was paid for it. In 1872 the contractor wanted to quit, but the company guaranteed to pay him ten dollars per yard for the remaining ten thousand yards, and yet he had no profit. The actual average cost was five dollars and seventy nine cents per yard, and at the time the average cost of hard rock tunnels in the United States was five dollars and eighty-nine cents. At that time out of three hundred tunnels, only twelve were longer than No. 3.

The following figures relate to tunnels built in that vicinity:

	Length.		Cost per Foot.	Total Cost.
The West Wisconsin Tunnel....	881.5	ft.	$43.01	$ 37,913.00
New Greenfield Tunnel........	1230	"	60.54	80,518.00
No. 1—North Western Tunnel..	1694	"	58.44	98,971.00
No. 2— " " " ..	1594	"	47.40	75,557.00
No. 3— " " " ..	3810	"	64.90	247,272.00

A flat car with frame on was run through to test dimensions. The average dimensions were 16″ × 19″ clear.

Once a year the tunnels are generally examined and loose stuff shaked down. The shafts were filled up. No. 2 was lined when in operation. Iron centers were used, made of rail on three feet centers, using sixteen feet lagging. Four brick rings were put in.

Three different rigged flat cars were used to do the lining. One for the footing and lower wall, one for the intermediate portion and one for the top.

The ventilation was toward one end or the other according to the direction of the wind.

TOPOGRAPHICAL AND CADASTRAL SURVEY OF ILLINOIS.

REPORT OF A COMMITTEE OF THE WESTERN SOCIETY OF ENGINEERS. H. B. ALEXANDER, CHAIRMAN.

[Presented September 2, 1891.]

Your Committee on Topographical and Cadastral Survey of Illinois has the honor to report as follows:

After investigating the work that has been done by other states and nations in the way of topographic surveys, as detailed in various reports that have reached us, we were made aware of the great importance of an enterprise of this kind to every interest of the state, and herewith present in some detail the advantages that may be expected from such work in the state of Illinois under the heads of Agriculture, Mining, Transportation, Municipal Affairs, Science and Education, following these statements with an estimate of cost presented from different points of view, and closing with a brief description of similar works in other countries and of other states of the Union, and recommendations regarding future actions for the society.

By the term "topographical survey" is meant such a survey of a portion of the earth's surface that a miniature or map of such surface may be reproduced, showing accurately the relative positions of the various points and objects in distance, direction and elevation. It determines the elevation of the land above the sea level or other surface of reference, as well as horizontal distances and directions, and differs from ordinary land surveys in that it is more complete by reason of introducing the vertical element, and thus defining all the surface features—plains, hills, ridges, valleys, lakes rivers and other drainage lines. The survey proposed for this state differs from the public land surveys which were made long ago, in that it is to be based on the precise trigonometrical surveys of the United States Government. It may seem that this survey will cost a large sum of money, and that it is difficult to show a definite return for the expenditure; but that great value in a general advantage to the state will accrue cannot be gainsaid, and the experience of those countries and states that have undertaken such enterprises demonstrates this. Some of the beneficial results may be stated as follows;

1st. In Agriculture.—This survey will be of great value to the agricultural interests by reason of the definite and uniform results obtained regarding land lines and corners. The determination of standard meridians and standard lengths will tend to uniformity in the land-surveyor's work, and lessen the liability to litigation on account of variation in lengths of measures and in magnetic declination used.

The topographic maps would show at a glance the various drainage basins, thus furnishing data for laying out drainage districts and determining grades and sizes of drains and ditches, without an expensive survey in each particular case.

In connection with the results of Geological investigation, the flow of the sub-surface waters could be approximately determined and depths of wells, especially deep artesian wells, inferred without hazardous experiment at great cost.

The large scale maps may be used by the assessors in the assessment of lands, thus saving to counties the frequent expense of providing the usual assessor's maps.

It is always a source of considerable satisfaction to the land owner to know the elevation of his land above sea level, or above Lake Michigan, or its relation to some local feature such as a certain lake or pond. As the expense of learning these facts is insignificant it would seem good policy to gratify such a sentiment of curiosity, which has a tendency to increase interest in local resources and advantages, and leads to improvements of a permanent character, with general ultimate benefit to the State.

2d. In Mining.—The mining interests of the state would also be benefitted by this survey by co-ordinating with it, the results obtained from the geological survey.

Inspection of the topographical maps with a knowledge of outcrops of strata and their dip and strike would enable the miner to determine the depth to coal or other mineral seam at any locality underlaid by the same.

It would greatly assist the land owner to an understanding of the probable value of his holdings beneath the surface of the land in the coal regions.

3rd. In Transportation.—In laying out wagon and railroad lines, and in the discussion of canal transportation, the overflow of rivers, etc., this survey would be invaluable.

The builder could determine without instrumental survey the general location of new lines. He could figure out cost of construction in the matter of graduation, bridging, etc., also questions of water supply, the maximum grade to be adopted, the amount of curvature, and in general all information determined by reconnoisance and preliminary surveys, and thus determine at small cost the feasibility of a proposed road or canal.

Investigations regarding water ways could be carried on in the early stages by reference to the detail map, which will show areas for reservoirs, canal grades, location of locks, and with rain fall data and discharge

observations results equal in value to the chart studies in road location would follow.

Studies of overflowed lands and drainage of swamp lands would be greatly facilitated, and methods of reclamation determined at small outlay of capital—no mean advantage in the early stages of the development of such schemes.

4th. In Municipal Affairs.—A topographical survey would be of great advantage in cities and towns that are considering sources of water supply and methods of sewage disposal. The information derived therefrom could be used in great part in determining locations of impounding and distributing reservoirs and stand pipes or tanks.

It would show, in connection with geology the probability of artesian water supply and possible contamination in shallow wells or surface supplies. It would show the feasibility of sewerage plans, the location of outfalls and of intercepting sewers. It would show the areas to be drained, average grades of sewers, the amount of flow to be provided for in fixing sizes of sewers, all without appreciable expense for special survey in each instance.

5th. In Science.—In the department of science the survey would be equally valuable. In geology it would enable the student to so corrrelate the facts and information already obtained by the geological survey as to be of immediate practical value, as the reference previously made will show.

In fact, modern geology requires the aid of hypsometry for the complete exposition of its results, and for the correct solution of the complicated problems arising in physical, chemical, stratigraphical and glacial geology, and in the determination of the value of soils and sub-soils.

In natural history, in meteorology, in sanitary science, in political economy and statistics, the topographic map would have great value.

6th. In Education.—As a feature of special interest, attention is called to the value of the detail maps, resulting from such a survey, from an educational point of view.

In the ordinary maps, no method of showing difference of elevation is used, though just as important as a matter of study as the elements of distance and direction.

A topographic map would do more to establish correct comparative knowledge of the different parts of our state or with the other states, than any other means at the disposal of the teacher. These maps with contour intervals colored with tints of varying intensity, would show at a glance the drainage basins, the divides, the valleys, hills, mountains, swamps, lakes, forests, etc., in so vivid a manner as to impress the mind of the pupil, and make the study of geography and maps a pleasure.

In all branches of education the tendency is to exactness of information, and it is certainly necessary for a correct understanding of geography to know the value of contour lines or lines of equal elevation.

One of the essentials in map work and study should be the use of these lines, and the pupils should be constantly drilled in drawing off profiles of areas and in making relief maps by cardboard or sand.

The following extract from the Educational Reports of the Royal Geographical Society shows the attention given to map study in Germany:

"One of the most difficult tasks to accomplish in teaching geography is to get the pupils to realize what a map is and to read it. One of the most successful geographical teachers in Germany, Dr. Lehmann, devotes a large part of the fist three years of his course to this purpose. He constantly exercises his pupils during that time in precise map drawing after himself on the blackboard or from the Zeichen atlas; makes them thoroughly understand the significance of all the symbols used to represent graphical features; trains them carefully in the use of contour lines and graduated mountain shading, scales, and so on. Of course this is possible only in a country in which school maps and atlases are executed with scientific precision."

Further on in the report is the following:

"Another method of teaching the significance of cartographic symbols I found in the secondary school in Zurich, in a class, the pupils of which were about twelve years of age. Taking the carefully drawn maps for the purpose in the beginning of Wellstein's fine school atlas, the pupils are made to cut out pieces of card board for the different levels, and so build up a relief, which enables them to realize what the symbols signify. As the contours are combined with carefully graduated mountain shading, the pupils thus come to learn the significance of the customary symbols.

"The aim in Germany, at least among good school cartographies with the approval of the best geographers, is to produce accurately and clearly drawn maps on the basis of the most effective cartographic methods."

COST.

From a comparison of the costs of surveys in the United States and Europe, and estimating a continuance of the survey over a period of 20 years, we feel confident that an expense of one dollar per square mile per year would be ample to complete a thorough topographic survey, and publish the results. As the area of the State is about 56,000 square miles. This would require an average expenditure of $56,000 per annum for 20 years to complete the work. At one dollar per square mile per year, this would amount to 25 cents per farm of 160 acres, or an expenditure of $5 in 20 years, or a trifle over 3 cents an acre, or 1-7 of a cent an acre per year.

In this state there were enrolled in our schools 778,319 pupils in 1890. These children cost the taxpayers some $15.51 per pupil for the year, or at a rate of 8½ cents per school day each.

A certain amount of geographical study is required of each pupil, and an analysis of the question would, we believe, show that were more care taken in the teaching of local geography, and especially of our own State, great benefit would result in retaining numbers of our citizens who, under the influence of the immigration bureaus of the states and territories west of us, are enticed away from the best to the poorest regions, from fertile fields to barren wastes, from the old home influences to inhospitable surroundings.

An appropriation of $56,000 per year for this survey would be less than 8 cents per pupil, or the extra expense per pupil per annum would be less than ½ of one per cent. of the present cost, or, instead of $15.51 it would be less than $15.59 per pupil each year, or it would only amount to about the cost of one day's schooling for the scholar per year. Can any one claim that such a small addition to the cost of education would not be fully repaid in the increased value of the instruction obtained?

To the people of the state at large, numbering some 4,000,000, the cost of this survey would be in amount the insignificant sum of 1¼ cent per individual per annum, or 6¼ cents for the head of a family of five.

This 6¼ cents represents about a half hour's labor in the year at the lowest wages, and doubtless more time than that is devoted each year to an unsatisfactory study of existing maps for information that could be obtained at a glance from the proposed topographical map. The parent now devotes 36 days, or 360 hours, or 720 times this amount of time, on the above wage basis, in the education of his children each year. Why should one object to devote one half hour of his time per year to the securing of a topographic map of Illinois, without appreciable loss to himself, and with great gain to his children and to the state?

From the foregoing we think it is evident that every individual of the state would derive benefit from this survey. First, during the school period in elementary education and discipline, and afterwards in business pursuits and in valuable technical information that will result in personal financial benefit. But this work is pre-eminently a state affair, and only possible by state authority and financial support, and the results following from it are of general value to the state.

It is singular that in this great commonwealth, with so many divers natural and artificial resources which would immediately be advertised to the world at large, and with a basis for the work already prepared by the General Government, it is singular that no effort has hitherto been made for the establishment of a proper bureau for carrying out this great service to the state. As our cities of enterprise do not hesitate to expend money in the proper advertisement of advantages for business and residence, so, too, our state as a whole should take a similar course and prepare information calling attention to the superlative natural advantages awaiting development. Chicago has become the second city of the Western Hemisphere by persistent effort in this direction, and the states west of us have by similar means drawn heavily upon our population to our detriment, as the recent census shows. The World's Fair will be held within our borders in 1893, and $1,000,000 will be invested to exhibit to the world our great state. This unquestionably, is a worthy cause, yet the benefits arising therefrom will be small compared to the perennial benefits we should receive from the results of the survey that your committee is endeavoring to promote.

EXAMPLE OF OTHER COUNTRIES AND STATES.

It may be of interest to call attention to surveys undertaken by other nations and by other states of the Union.

Great Britain has been engaged upon a topographic and cadastral survey of the Islands for a hundred years past. Their survey has been carried on with so great a degree of detail, and with such exactness as to have cost $200 per square mile, and yet it has been considered one of the wisest expenditures of funds that could be made by the government.

France has been at work for 90 years on the accurate geodetic and topographic survey of its domain. The results are published on large scale maps of five inches to the mile. This work has cost from $30 to $50 per square mile.

Switzerland has been engaged similarly for 50 years. In 1870 work was commenced on a special topographical atlas, the scale adopted being about 2 inches to the mile, with contours about 30 feet apart.

Italy is also engaged on an accurate survey, resulting maps on scales of 1 and 2 inches to the mile.

Belgium began work in 1866 and publishes maps of 3 inch scale.

Holland has a new topographic map, scale same as Belgium.

The various German states are carrying on special topographic and geologic surveys, and publish maps constructed to a 2½ inch scale.

Denmark, Sweden, Norway, Russia and Turkey are all engaged similarly with accurate surveys.

Austria-Hungary, recently began her new topographical map. Scale used about one inch to the mile.

Spain and Portugal are at the front with thoroughly scientific work, and with resulting maps of one mile to the inch for Spain, and two miles to the inch for Portugal.

India commenced work on the great Atlas of India in 1856 with scale of four miles to the inch. There will be 177 sheets when completed.

In the United States, New Jersey has taken the lead in the completion of an accurate topographic survey with published atlas, scale one inch to the mile, and with contour intervals of 10 to 30 feet.

Massachusetts has recently completed her second survey, but the results have not all been published.

New York was engaged for several years on a trigonometrical survey under the direction of the state engineer. Especial attention was paid to the topographical work in the Adirondacks, and rectification of county lines. This work was abandoned some years since because of the mistaken policy of too great a refinement in work without securing practical results.

Minnesota has, in connection with the geological survey, been engaged in topographical work.

Connecticut also has recently established a survey of similar scope.

Special work has been done in Michigan and Wisconsin in the mineral regions of those states.

Missouri has reorganized the geological survey of that state in which topography has a prominent place.

Georgia, North Carolina, Texas and Arkansas have done some

considerable work in this line with promise of great benefit to those states.

The United States government is working up a general topographic survey and publishing results on scales of 4 inches and 1 inch to the mile. This work is carried on by the United States Geological Survey at a cost of from $3 to $5 per square mile; and only needs to be supplemented by our efforts and appropriations as an individual state to give the valuable results above referred to.

In conclusion we would recommend that this committee or one to be appointed for the purpose, embark in a campaign of active promotion of methods for securing by legislative enactment provisions for carrying on this survey. To do this work successfully, will require some money for postage, stationery and printing circulars for diffusion among the various interests that would be benefited by the work. It might be well for the society to devote some thought as to ways and means to provide for such promotion fund.

We have over a year now in which work may be done before the next legislature meets. A bill should be carefully formulated and discussed, and should then be presented at the beginning of the next session of the general assembly, and a committee able and willing to appear before committees and argue the merits of the proposed measure should be appointed.

All of which is respectfully submitted.

Committee:—H. B. Alexander, Chairman, C. McLennan, Chas. Hansel, Bernhard Feind, F. C. Rossiter.

PRACTICAL TESTS OF COMPOUND LOCOMOTIVES.

BY C. H. HUDSON, MEMBER WESTERN SOCIETY OF ENGINEERS.

[Read October 7, 1891.]

Considerable attention has been paid during the last few years to the use of steam more expansively in our locomotives, and in view of the triple and quadruple expansion in marine service it would seem not unreasonable that we should in some way be able to compound them.

This has been done in a variety of ways and many tests have been made of each type, and some good results, as far as economy in fuel is concerned, have been reported. As a rule, these tests have been for short or single runs where the coal has been weighed and the water measured, but quite frequently other conditions have been neglected and the engines have been so different that no comparisons could be of value in fixing the rate of economy, though they may and do doubtlessly point out the fact that there are savings.

As an instance, I recall a test where a new (or rebuilt) compound was tried against an old engine of *about* the same size. The result showed

over 20 per cent. saving in *fuel* and almost nothing in *water*. Were we to analyze the conditions we undoubtedly would have found in the compound clean flues and a clean fire box, while in the other more or less scale on both. Usually a skilled man will have charge of the engine we expect to make the good showing, and thus we get results from that which are not normal and cannot be reached in every day work. How the working parts compare is not known, but there may have been some difference there.

It is not to be presumed that there will be any intention of making wrong comparisons, but they simply follow an over anxiety to show remarkably good work from the engine tested. The liability to these errors must be reduced to a minimum to make our tests of full value. We must have a simple engine of an economical character, for a comparison with a poor steamer or one that did not do its work economically would be of no value. All conditions should be alike, save the compounding, and then the engines should be manned alike and have the same character of fuel, substantially the same loads, weather, etc. Further than that, the trial should be of sufficient length to carry it down to every day work, and should cover the changing of engineers and firemen, as well as all the vicissitudes of weather and work. In no other way can we answer the criticisms or overcome the scepticism of many regarding the value of the compounding principle. We must be able to show that we not only do save fuel, but that we do not have excessive repairs arising from the changes in machinery.

It is of a trial of this character that I write, the compound engines being of the two cylinder type. This paper is intended simply to show what *these particular engines did*, and not to demonstrate that other engines or types would or would not do just as well.

The writer was able to cause this test from the fact that in ordering a lot of engines he had one 10-wheeled passenger out of three built on the same specifications compounded, and two consolidation freight engines out of eighteen, on the same specifications, compounded.

The engines were all built by the Schenectady Locomotive Works and the compounding valves were of the Pitkin design.

The weight of all of these engines was the same, 126,000 lbs., without the tender, and they were delivered and put into service about the same time.

The simple consolidation engines were $20 \times 24''$ cylinders, while the compounds were $20\frac{5}{8}$ & $29 \times 24''$. The cylinders of the 10-wheeled simple engines were $19 \times 24''$, while those of the compound were 19 & $27 \times 24''$.

The consolidations were substantially duplicates of a large number of other engines of the same character which after some years' use had been worked up to a very economical point.

During the previous year we had procured a 10-wheeled passenger engine, which had been changed experimentally until it had become unusually economical in fuel. This was the basis of the three new 10-wheeled engines, and they were found most excellent in their workings.

The 10-wheeled engines were put in service Sept. 1, 1890, and run upon

the eastern end of the East Tennessee, Virginia & Georgia Railway, upon a run of 131 miles and over grades nominally 69 ft. maximum and very long, (some of them actually 77 ft.) with 45 per cent. of the line curved, from three to eight degree curves, and not equated. Thus we had grades and curves combined equal to about 85 ft. tangent grades.

There were three regular trains *each way*, two of them each way, or four trains, weighed an average of 440,000 lbs. and occasionally running up to 530,000, and ran at a speed ranging from 32 to 38 miles per hour. The other two were usually of 155,000 lbs. weight, but occasionally ran up to 250,000, and ran at a speed of 27 miles per hour. All made part of the stops and some made all.

The 10-wheeled passenger engines were put on these runs, following each other around, four being in the runs a part of the time, and three a part of it. In this way they all got the heavy fast trains at times, and all got the light ones. This service has been kept up until the present time.

The work done from September 1, 1890, to June 30, 1891, a period of ten months, is taken as a test of the engines, and a measure of the value of the principle of compounding.

The two consolidation compounds were placed on the same division and for six months ran the road with many other engines, but especially with four new simple engines of the same age, build, specifications. etc., following each other around and changing men about the same time.

They were then placed upon the western division of the road, where the grades are lower, being 60 ft. maximum, and with somewhat less curvature, but not equated. As in the other case, four engines of the same age, build and size, specifications, etc., etc., were compared with our compounds, running the road with them and changing engineers and firemen the same.

These tests for ten months with the passenger engine and eleven months with the freight, should certainly show the every day work of the engines.

Several short tests were made by Mr. Angus Sinclair. The coal was carefully weighed, water measured, indicator diagrams taken and the vacuum in smoke box measured, etc.

The statement below is taken from his report:

Distance from Knoxville to Coal Creek and return.....62 miles.

Grades.......................................70 to 90 feet.

	SIMPLE. Load in lbs.	COMPOUND. Load in lbs.
Knoxville to Coal Creek...............	689,100	734,050
Coal Creek to Knoxville...............	1,313,050	1,290,450
Total.......................	2,002,150	2,024,500
Coal used............................	7,040 lbs.	5,073 lbs.
Saving of coal.........................		1,967 "
Per cent......................		28%

Water used	49,788 gals.	41,058 gals.
Saving of water		8,730 "
Per cent		18%

Mr. Sinclair says: [*National Car and Locomotive Builder*, Nov., 1890.]

"The methods of measuring coal and water were not satisfactory, the latter being particularly open to error, owing to the curves and grades at the points where measurements are necessarily made. * * * * * * The simple engines labored under two disadvantages during the return trip, not experienced by the compound. A car in a preceding train had dropped grease on the rail which caused considerable slipping and sanding of rail, during the ascent of a four-mile grade, and the train was held twice for orders. * * * * * * On the other hand the compound doubled one hill, her return train seeming to pull harder than the train of simple engine, notwithstanding that it was eleven tons lighter."

Other trials were made, one of which is shown below, being a trip from Knoxville to Bristol, 131 miles, and return, with a simple and a compound engine under substantially the same conditions, as to weather, time on trip, etc.:

	SIMPLE.	COMPOUND.
Weight of train, Knoxville to Bristol	1,290,710 lbs.	1,377,550 lbs.
" " " Bristol to Knoxville	1,228,020 "	1,196,000 "
Total	2,418,730 "	2,573,550 "
Excess of work done		154,820 "
Per cent		6.4%
Coal consumed	29,728 "	23,080 "
Saving in coal		6,648 "
Per cent		22.4%
Water consumed	34,535 gals.	19,200 gals.
Saving in water		5,335 "
Per cent		21.8%

But the compound did 6% more work, which would add to the percentage and make the saving shown about 26%.

These results were in the same line as the others, but still the tests are open to errors, as in the other case.

The comparisons of the 10 months' work of the passenger engines are hown in the following tables:

COMPARISON OF PASSENGER ENGINES.

	Miles run.	Car miles.	Av. cars pr. trn.	Lbs. coal consumed.	Lbs. coal pr. cr. mile.
2 Simple Engines	107,885	564,995	5.23	6,263,654	11,086
1 Compound Engine	48,100	254,204	5.17	2,097,911	8,252

Saving 2.834 pounds of coal per car mile, or 25.56%.

The work of 4 simple and 2 compound freight engines for eleven months is shown as follows:

SIMPLE ENGINES.

	Miles run.	Car miles.	Av. cars pr. train.	Lbs. coal consumed.	Lbs coal pr. cr. mile.
4 engines, East End, 6 mo..	81,226	1,335,045	16.43	8,252,533	6.132
4 " West " 5 " ..	61,318	1,190,786	19.41	5,977,917	5.029
Total..........11	142,544	2,525,831	17.23	14,230,450	5.634

COMPOUND ENGINES.

	Miles run.	Car miles.	Av. cars pr. train.	Lbs. coal consumed.	Lbs. coal pr. cr. mile.
2 engines, East End, 6 mo.	27,682	495,050	17.88	2,454,142	4.957
2 " West " 5 "	31,550	712,291	22.57	2,667,505	3.746
Total............11	59,232	1,207,341	20.38	5,121,647	4.242

Saving 1.392 pounds of coal per car mile, or 24.70%.

Here we have a marked saving in a year's work. We believe the conditions were such that the test is of much more value than were the first ones made, as they show the every day work of the compound engines compared with exactly the same simple engine under the usual working conditions. No tests can be fairer and I have seen none of more value.

I regret to state it, yet it is true, that there was at the start a universal prejudice against the compound among the engineers and firemen. They were pronounced failures before they were set up, and long after they had shown their good qualities the unfavorable criticism continued. They "would not start the train," but they did it. They "could not run up the long hills," but some how they did it quite as easily as the other engines. They "could not pull within 2 or 3 cars of the other engines," but a year's work shows they averaged larger trains and in repeated cases they have pulled as heavy trains as any engines on the road.

But when they saw the compound passenger engine run the round trip with a tender of coal, and run easily a hundred miles with one tank of water, they had to admit that there was some good in the new departure.

It is our belief that this test of nearly a year in every day work, with changing engineers and firemen, against exactly similar simple engines, doing the same work at the same time, is more valuable than any tests yet reported in this country, and demonstrates beyond a question the value of the compound principle in locomotive engines, in the matter of coal consumption.

The importance of this is seen when it is known that the cost of fuel is about 10% of the whole cost of operating, and when we consider that the 32,000 locomotives in this country probably consume 30,000,000 tons of coal per annum.

There is, however, another matter to be considered, and it is one that has rendered American engineers sceptical as to the real value of the compound engine. That is one of repairs, as well as first cost.

It stands to reason that the cost of maintaining three cylinders or four cylinders will be larger than the cost of maintaining two. To what extent this excess will be found it is not known.

During the four first months of our use of the compound engines we made quite a number of changes, hoping to improve them. This was not

necessary to keep them running and should not be construed as running repairs in any comparison with other engines.

The intercepting valves were changed in various ways and the cylinders bored out, upon the consolidations, from 20 to 20⅝, giving the power which Mr. Sinclair mentions as being deficient, as compared with the simple engines. This work was all done by December, and in order to ascertain how the running repairs of the compounds compared with those of the simple engines, I have a report of the repairs upon the engines under consideration from January 1st to June 30th, 1891, a period of six months. while they were running together, and for six months of the time in which the consumption of coal is considered. Considering first the freight service, we find that the

4 Simple Engines in 6 Months ran	76,827 Miles
Total cost of running repairs done	$1,312.66
Cost per mile run	1.70c.

In the same time and over the same ground, the

2 Compound Engines ran	39,268 Miles
And the running repairs cost	$612.72
Or per mile	1.55c.

Showing that for this six months the compound ran more economically than the simple, as far as repairs are concerned.

It is quite propable, however, that in another six months this would be evened up and the cost per mile would have likely been equal to that of the simple engines.

It should be borne in mind, however, that the compound engines did more work; that is, hauled more cars.

The Simple hauled	1,456,978 Car Miles,
Or per train	19 Cars.
While the Compound hauled	835,830 Car Miles
Or per train	21.3 Cars

During the same six months the

2 Simple Passenger Engines ran	69,220 Miles,
Cost of Repairs	$1,213.12
Or per Mile run	1.75c.
While the Compound Passenger Engine ran	29,864 Miles,
Cost of Running Repairs	$527.51
Or per Mile run	1.77c.

Substantially the same as the simple.

The work done by the compound [average cars per train] was slightly less than with the simple engines, but not enough to make any perceptible difference.

These figures of course do not include any general overhauling, as the engines were all new, but did cover the every day work needed to keep our engines up to the standard.

How much the general overhauling may be affected by the compounding cannot be determined by so short a trial. I see no reason, however,

why it should add materially to it. It is true our pressure is a little higher, but we use less coal, and we have not been able to discover thus far any different effect upon the fire box than that upon the simple engines.

When we consider that with cheap coal [say $1.50 per ton] the cost per engine mile for fuel is for freight trains about 7c. per mile, and for passenger 4½c. we can see that a saving of even 20% in fuel means over a cent a mile, and that it cannot be outweighed, by any reasonable, or I may say possible, increase of repairs, as but a small part of such repairs pertain to or are affected by the parts compounded.

We believe this to have been a good practical test of the two cylinder type of compound engines, and while no claim is laid to perfection, it seems to have covered a sufficient length of time, amount of work and variety of climatic and other conditions to have overcome the influence of any prejudices, or efforts for or against any particular engine or of any special skill, on the part of any one man that in a short run or experiment might have a marked effect.

It seems safe to conclude that the compound principle as developed in these engines is a valuable improvement upon the simple engines and that its increased economy in fuel is of sufficient magnitude to more than overcome any possible increased repairs.

STEERING GEAR ON VESSELS FOR LAKE SERVICE.

BY WALTER MILLER, MEMBER, CIVIL ENGINEERS' CLUB, CLEVELAND.

(Read June 9, 1891.)

It is a difficult matter to describe anything used on ship-board to a landsman. Evidence of this is seen every time a sailor is placed on the witness stand in a court of justice, the sailor and the lawyer are soon at loggerheads. In fact, a sailor is a very peculiar individual; machinery of almost any description that requires to be oiled and adjusted he has no use for whatever. If any particular thing needs to be painted he is right on hand and will paint it in all the colors of the rainbow, or in polishing up brass-work on board, he will soon have it like burnished gold.

Before steam gearing was applied to steering our Lake vessels the construction of the hand steering gear was very light compared to that used at the present time. A pair of wooden wheels, fitted to a drum, set up on standards in the pilot house, and chains or wire rope wound around the drum a sufficient number of turns to prevent slipping. The purchase usually consisted of a double and single sheave block thus making a purchase of three to one and generally located in a perpendicular part between the wheel-stand and the spar or main deck. The single part of the wheel ropes after leaving the purchase blocks was led down under the deck and to the ship's side, then aft along the ship and around sheaves abreast

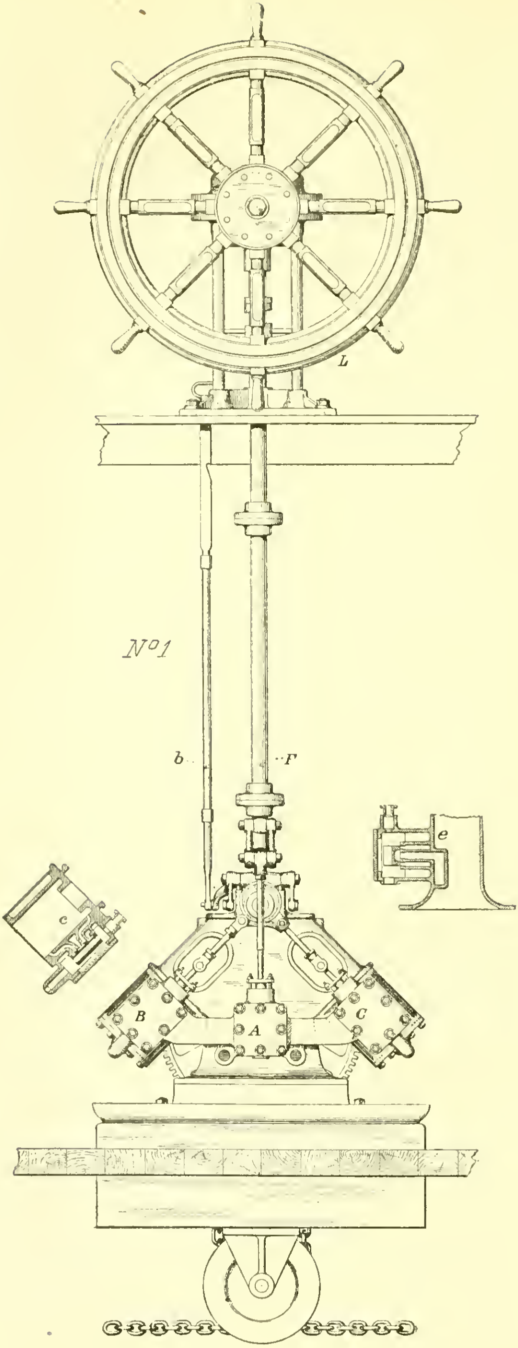
of the tiller, then made fast to a sleeve on the tiller. These sheave blocks that were used to guide the tiller ropes around the corners were usually made from 6″ to 8″ diameter and fitted into an oak block with a rough iron pin for the sheave to turn on and no means for oiling. These oak blocks were bolted or spiked to the deck beam and the fairleaders at the ship's side to take the weight of the tiller rope were of a similar construction. The salted moisture from the brine used in salting the ship soon rusted these sheaves and pins solid. The wheel ropes were usually ½″ or ⅝″ diameter of wire and as soon as steam steering gear was applied to it soon gave out and the trouble began.

To the writer's knowledge steam was used for steering for the first time on vessels for lake service in 1878 and on the steamer "Onoko." This steerer was known at that time as the Sickle's Patent and was built at the Morgan Iron Works, New York City. A hand steering gear about as described above was used, only made heavier, and one of the large steering wheels in the pilot house had a "V" groove turned on the rim to receive a rope belt from the steering engine. The belt used was a piece of good manilla rope and tightened up to its work by a sheave in a sliding frame, which could be slacked off at will and leave the hand gear free to steer by hand. This steerer worked fairly well until about a year ago when it was replaced by a more modern and improved steerer.

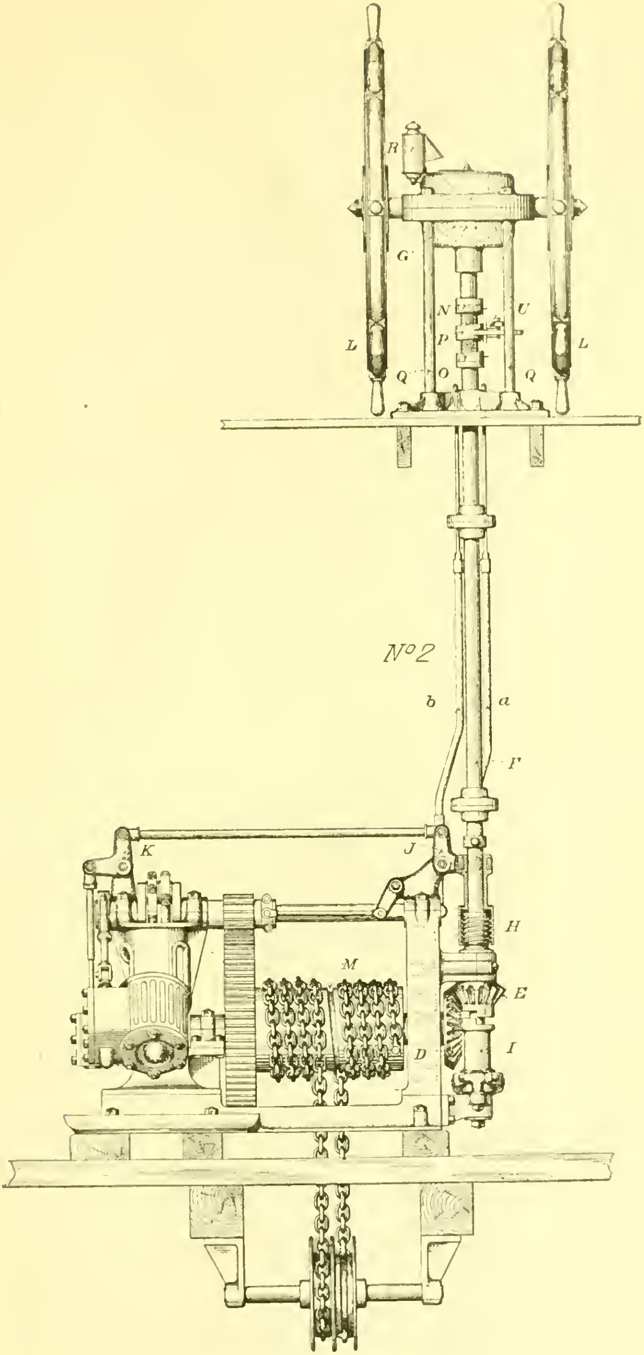
It would be impossible to describe all of the steam steering gear in use, therefore, will divide them up into three classes and describe each class. The first class we will take, if you please, the rope belt steerer similar to that described for the steamer "Onoko." These steerers worked with very little noise, but the rope belts are short lived and liable to part at a time when most needed. The second class may be styled a direct geared steerer, that is, the steerer was geared in such a manner that the tiller ropes led direct from the steering engine to quadrant on rudder stock and the engine geared to the drum by worm gearing. This class worked well, only objections are made to the tiller ropes leading direct from quadrant to steerer drum for the reason that when a heavy sea strikes the rudder the gear will not give and relieve the shock. The ratio of gearing between the engine shaft and drum shaft on this class of steerers is so great that the engine works at a very high speed and is very destructive on itself. Some of them make about 150 to 160 revolutions from hard over to hard over, and with steam cylinders 5″ or 6″ bore by 6″ or 8″ stroke running at this speed, gives off quite a power. The third class to which your attention will now be called is of the indirect geared steerer similar to the views Nos. 1, 2 and 3 on the blackboard. This class of steerers is geared but tiller ropes do not lead from the steerer drum direct to quadrant, but to a three-fold purchase, that is, one sheave sliding block and a two-sheave stationary block, the chain from the quadrant being made fast to the tail of the sliding block, thus it will be seen the shock of the sea striking the rudder will be taken off to a large extent through this purchase. Furthermore when the hand gear comes into play, the purchase being greater it is not so hard to steer by hand.

The application of the steam steerer shown on the illustrations Nos. 1,

2 and 3 may be described as follows: There are two steam cylinders of 7″ bore by 6″ stroke placed at right angles to each other, connected to the crank shaft and geared to the chain drum using cut spur gear with a ratio of six to one; this gear works noiseless and the motion of the engine very smooth and even. Steam is admitted to the middle chest at "A" and is delivered to the steam chests "B" and "C" as an up and down motion of the valve in chest "A" may direct. How this is done will be described later on. The bevel gear at "D" on end of drum shaft gears into a bevel pinion "E" on the upright shaft leading to the wheel stand in pilot house. The upright shaft "F" is geared to the steering wheels by miter gears "G" in wheel stand; the bevel pinion "E" on the upright shaft has a screw cut on its upper end and engages the brass nut "H" and has a clutch formed at its lower end to engage the sleeve clutch "I;" this bevel pinion is not keyed to the upright shaft but is independent of any movement of the upright shaft; the brass sleeve nut "H" is feathered to the upright shaft and revolves with it but is free to slide up and down as the upright shaft is revolved; the upper end of this sleeve nut is turned out to receive a pair of clamp collars with trunions formed on them to engage the bell cranks "J;" these bell cranks pivot on a bracket formed on the bearing cap and the upper ends are connected to a similar pair at "K" which are in turn connected to the valve spindle of valve in chest "A;" the operation of the gear is as follows: By turning the steering wheels "L" the upright shaft is revolved in either direction as may be desired, the brass sleeve nut is constantly raised or lowered thus giving motion to the bell cranks and in turn to the valve in chest "A" admitting steam to the cylinders and move the pistons in either direction as the valve in chest "A" may be moved; as the engine moves it turns the chain drum "M" and as the bevel gear "D" is keyed fast to the drum shaft it turns the bevel pinion "E" and screws the brass sleeve nut "H" back to its normal position, thus through the bell cranks and connections to valve in chest "A" steam is shut off from the cylinders and the engine stops and cannot move until a further movement of the upright shaft. It will be seen that anyone turning the steering wheel "L" need have no knowledge of the steam power doing the work; they have but to simply turn the wheel in the direction it is desired to have the vessel's head move and the steerer takes hold and does the rest. The steering wheels are prevented from being turned farther when a hard-over position is reached, by the lock nuts "N" and "O" engaging the traveller nut "P;" this nut travels up and down and is prevented from turning by the standard "Q." When the wheels are turned to within one-half revolution of the hard-over position, a pin in the lock nuts "N" and "O" engage striker on the bell "U" and an alarm is sounded to warn the wheelsman to stop turning and prevent jamming and straining of the gear and tiller ropes. At the top of the wheel stand is a pointer indicating the exact position of the rudder at all times, and is operated by a worm and gearing from the steering wheel shaft. There is a lamp "R," placed on the forward side of stand and shaded to throw light on the indicator at night. It is necessary in all classes of steam steering gear to have a powerful hand gear that can be thrown in and out of gear very



N° 1



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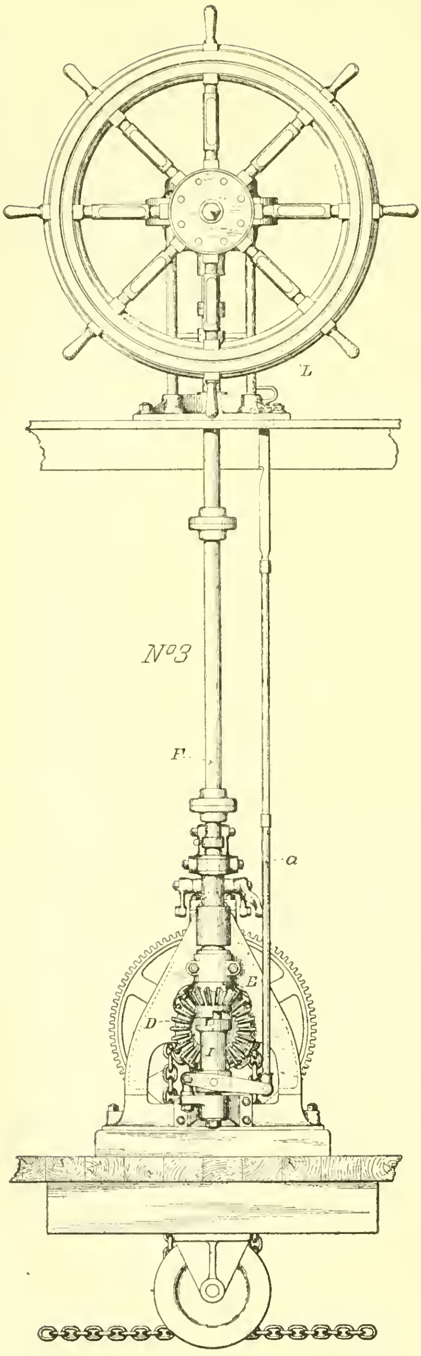
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quick in case the steam steerer stops which it is very apt to do at times when it is most wanted, and this is accomplished in the steerer shown here by making the upright shaft strong enough to transmit the power of four or six men at the wheels to chain drum through the bevel pinion in gear. The bevel pinion "E" is made to turn with the upright shaft but the clutch sleeve "I" which is pulled up in place by the shafting rod "a" and the engine is cut out of gear by having a spur pinion pulled back out of mesh with the spur gear on drum shaft by the shifting rod "b;" both rods "a" and "b" are led up into pilot house with the steering wheel stand and the ends are fitted with good strong pulls within easy reach of the wheelsman. A reverse of these movements puts the steam power in gear. The automatic movement described for controlling the valve in the middle chest "A" is common to all classes of steam steerers: in fact, it was used on the steam steerer built for the "Great Eastern" and believe it is the invention of a Mr. McFarland Gray, a Scotch engineer. It is understood that different styles of steerers use this movement in different ways to accomplish the same result, and is a very ingenious arrangement; if it was more generally known it could be used to good advantage wherever it is desired to have steam pistons under control. All the valves used in this design are of the slide pattern and will always keep tight. It will be seen from the sections "c" and "e," section "c" is through the valve and seat and chest of the steam cylinders "B" and "C" and is a section of valve and chest "A;" the valves in the cylinder chest do not have any lap or lead and are driven by one eccentric; steam is admitted full stroke from the under side of the valve and exhausts from the under side as well. The port that supplies steam to turn the engine one way serves as the exhaust port when running the other way. No steam is admitted to the cylinders from the steam chests but steam is admitted to the chests by a small passage from chest "A" simply to keep the valve up to the face only. It may be said in passing that the movement of the engines is controlled entirely by the escape of the exhaust, as a matter of fact the full steam pressure is on the pistons before the exhaust takes place.

Quadrants are now used where possible and chain for all the running parts and wire for the standing parts. ⅝" chain is used on the steerer drum and over, or under as the case may be, to a double guide sheave and led to quarter blocks at ship's side. The sheaves in these blocks are 24" diameter and are bushed with metaline bushings that do not require to be oiled The frames of these blocks are of cast iron and the lower parts are made in such a manner that it can be taken down, the sheave taken out, without taking the entire block down. The ⅝" chain is led aft far enough to have the standing part, or wire rope, clear the sheave in the blocks at the hard over position. 1" chain is used on the quadrant and is led through quarter blocks in a similar manner as at the forward end, only the blocks and sheaves are very much heavier to stand the strain of the single part. The chain from the quadrant is made fast to the sliding block of the purchase; ⅝" chain is used for the running part of the purchase and is shoed to the wire rope clear of the quarter blocks. As was mentioned before the ratio of the gear on the steerer is six to one and

that of the purchase block three to one, thus giving a purchase to the steerer of eighteen to one and the wheels in pilot house making ten to twelve turns from hard-over to hard-over the engine makes from 46 to 52 turns. It will be seen that the steerer has plenty of power to move the rudder at all times and at all speeds of vessel with very little wear and tear, as well as working almost noiseless.

The above is a description of about the best practice on these inland waters but it must be remembered that there are a number of well-designed arrangements for steering gear on these lakes as well as on seaboard ships, but any steam steerer that the automatic movements controlling the middle valve, if operated from the pilot house, is liable to fail at any time. The movement of the valve in middle chest must be very sensitive to the movement of the steering wheels. If the wheel has to be turned more than 1-16 of a spoke the steerer will turn just as far before it stops unless the wheel is righted which will cause the vessel to swing out of her course, therefore, it will he seen that the valve in chest "A" must be made to require very little movement to start and stop the steerer. It is obvious that any steerer that has this middle valve operated by bell cranks and rods from the wheel stand will give trouble, as any springing of decks or any change that may take place in the ship by loading or unloading affects this movement. As will be seen on referring to blue print No. 1 that the middle valve is moved by turning the upright shaft and any springing or twisting out of line is compensated for in the miter gear in wheelstand which is feathered to the upright shaft and is free to move up and down.

DISCUSSION.

Mr. Palmer:—In the first paper, by Mr. Miller, I was very much impressed by the mode of operating the valves. We had an arrangement like an ordinary locomotive has, but the device which he illustrates, I think is much more preferable, in fact the other mode would seem to be impracticable altogether. In this arrangement I was speaking of, the idea is in turning the wheel over it sets the engine in motion, which turns the rudder the same number of degrees that the wheel is turned and the engine stops of its own accord. This might be used in some other cases One of these is in the use of cranes in moving the weight by revolving the crane. If you turn the lever of the wheel a certain distance it will put the crane over a certain place. I think the principle is a very good one. I would like it if Mr. Miller would separate the parts of this method a little more fully.

Mr. Coburn:—Can very heavy loads be handled with the crane?

Mr. Miller:—A crane, unless it is a special one, cannot be used for general work. I think a crane could be designed for that purpose, but more especially for cranes or forges in steel works. In the first place they take the billet from the furnace; lifting the weight is one, swinging is two, and racking in and out is three. There are times that all of these motions have to be done so nearly at the same time that it would require the services

of a great many men to handle the weight, as the momentum of the weight is too great for the rapidity with which the three motions have to be made. The only other place that the automatic movement is used outside of steering engines, is in elevators. In these the direction is changed by taking hold of the hand ropes.

In answer to Mr. Palmer I would say, that I merely referred to the automatic movement of connecting the motion to the valves. The steerer on the Great Eastern sits well aft over the tiller ropes, very close to the rudder. There is an automatic arrangement near the wheels that is transmitted back to the engine. This is the first time I believe that the large wheels have been used exclusively for combined steam and hand steering.

Mr. Palmer:—The kind of crane I had in mind, is one for taking billets such as are used in steel works. They usually use hydraulic power in lifting it and changing the length of jib.

Mr. Brown:—We have used for several years automatic valves for that kind of work, but have found that at the proper time for shutting off the steam, in rounding curves, the momentum of the weight has been so great as to carry it far beyond the point intended. It is very hard to keep control of the weight after it has been put in motion.

Mr. Miller:—The one I spoke of is for use where the motion is very slow. To use it successfully you can have no velocity. In putting the brakes down the engine would stop instantly. The engines have no fly wheels and no centers. They will stop at any point and stop instantly.

Mr. Palmer:—I think the arrangement, as I understand it, is a very good one. If the jib is very heavy the momentum would carry it beyond the proper point, it would swing with the engine and would amount to the same thing as the moving of the wheel. It would automatically return, so that in all cases the jib would go to the place on the crane corresponding to the point at which the wheel is set.

THE SELECTION OF SOURCES OF WATER SUPPLY.

By Frederic P. Stearns, Member, Boston Society of Civil Engineers.

[Read September 16, 1891.]

As a part of my official duties, I have occasion to investigate many proposed water supplies each year with reference to the probable quantity and quality of water to be obtained. With so much of this work to be done it has become important to reduce the labor of computation as much as possible, and with this in view, the existing data regarding the yield of water sheds has been put in more convenient form for use than heretofore. I have also had occasion to gather some statistics as to the yield of

ground water sources. These features together with a somewhat extended general consideration of the quantity and quality of surface and ground waters make up the paper which I present to you to-night.

In preparing this paper, the examination of existing water supplies in Massachusetts,* which has been carried on for more than four years by the State Board of Health—in part under my immediate direction—has been of great assistance.

In selecting a source of water supply it is essential that all water should be rejected which is seriously polluted with domestic sewage. There are other waters not so polluted, as, for instance, those having a disagreeable taste and odor or drawn directly from swamps, which are manifestly unfit for drinking. A water may also be rejected by reason of its extreme hardness which makes it unsuitable for washing purposes and for use in boilers. Among the waters which may be used there is a large difference in quality, and this in connection with the quantity and cost should receive careful consideration in making the selection.

The prominent characteristic of ground water is freedom from color and organic matter (including microscopic organisms), while surface waters are frequently colored with vegetable matter derived from swamps, and almost always contain a greater or less number of microscopic organisms. These organisms, when abundant, frequently impart to the water a disagreeable taste and odor.

With regard to the question of quantity, sufficient surface water can be obtained for the largest cities, and the amount which can be obtained from a given water-shed can be estimated in advance with a large degree of accuracy. Ground water supplies, on the other hand, are much more limited in quantity, and the amount to be obtained from any given place cannot be as accurately predicted.

As a whole we may say that when unpolluted ground water can be obtained in sufficient quantity from regions where the water does not dissolve much mineral matter and in this way become hard, it is very much to be preferred to surface water for the supply of a city or town.

In this paper water taken from wells and filter-galleries built beside streams and ponds, and deriving their water in part, from these surface waters, by filtration, will be considered as ground waters.

Quantity of Surface Water.

All sources from which water is obtained depend for their supply upon the rain which falls upon the area from which the water can flow over the surface or underground to the point whence it is taken for use. In a great majority of cases this area coincides with the superficial water-shed of the stream or pond utilized. We have, therefore, as very important factors affecting the quantity of water, the amount of the annual rainfall and the area of the water-shed.

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*This paper, being based mainly upon observations in Massachusetts, has been written with especial reference to this State; in many respects, however, the statements made will have a wider application.

The whole of the rain which falls upon a water-shed does not flow off into the streams, because much is lost by evaporation from the surface of the ground. The amount of this loss has been determined practically by comparing the quantity of water falling upon a given water-shed (as deduced from the depth of rainfall and the area of the water-shed) with the amount of water flowing off in the streams. Very valuable records of this character have been kept by the city of Boston for many years at Cochituate Lake, Sudbury River and Mystic Lake, and the results have been published in the annual reports of the Boston Water Board. From these we learn that the average percentage of rainfall collected from these three watersheds is as follows:

	Average. Rainfall. Inches.	Average. Rainfall. Collected. Inches	Per Cent. Collected.
Lake Cochituate (28 years' observations), . . .	47.82	20.55	42.97
Sudbury River (16 years' observations), ...	45.80	22.67	49.50
Mystic Lake (13 years' observations), ...	44.11	20.22	45.84

In attempting to determine the quantity of water which can be made available for use from any given source, the above figures, representing the average results of many years' observations, have only a limited value, because there is a marked variation in the amount of rainfall in different years and a still greater difference in the amount of rainfall collected, the rule being that the percentage collected decreases with the amount of the annual rainfall; moreover, there is a vast difference in the amount of rainfall collected at different seasons of the year. In view of these differences it is obviously necessary to take into account the rainfall collected during dry periods of much less than a year's duration. This can be done by means of the records of the Boston Water Works above referred to. Of these the Sudbury River records are the most accurate and the most generally applicable to conditions existing at other places, and, on account of their value as a basis for water supply estimates, they are reproduced from the reports of the Boston Water Board in the following table. The rainfall collected is also shown graphically upon the diagram opposite page.

The most prominent feature of the table and diagram is the immense difference in the amount of water collected in the spring and in the summer; but the difference between the flow of different years is also very great. The dryest years were 1880 and 1883, in each of which there was a severe drought during the last seven months, and even during the spring of each of these years the amount collected was much less than in other years. The summer of 1889 was in marked contrast with all of the others, the flow being unprecedentedly high.

As has already been indicated it is necessary in estimating the capacity of sources of water supply to take into account the dryest periods which have occurred, and which consequently may recur; and for this reason it

Rainfall Received and Collected on the Sudbury River Water-shed.

Month.	1875. Rainfall.	1875. Rainfall Collected.	1875. Per Cent. Collected.	1876. Rainfall.	1876. Rainfall Collected.	1876. Per Cent. Collected.	1877. Rainfall.	1877. Rainfall Collected.	1877. Per Cent. Collected.	1878. Rainfall.	1878. Rainfall Collected.	1878. Per Cent. Collected.	1879. Rainfall.	1879. Rainfall Collected.	1879. Per Cent. Collected.	1880. Rainfall.	1880. Rainfall Collected.	1880. Per Cent. Collected.
	Inches	*Inches*		*Inches*	*Inches*		*Inches*	*Inches*		*Inches*	*Inches*		*Inches*	*Inches*		*Inches*	*Inches*	
January,	2.42	0.184	7.6	1.83	1.147	62.7	3.216	1.174	36.5	5.632	3.228	57.3	2.478	1.249	50.4	3.566	2.000	56.02
February,	3.15	2.411	76.5	4.21	2.282	54.2	0.739	1.529	206.9	5.973	3.972	66.5	3.562	2.756	77.4	3.980	2.982	74.92
March,	3.74	2.862	76.5	7.43	7.911	106.5	8.357	8.586	102.7	4.689	6.256	133.4	5.140	4.156	80.9	3.315	2.451	73.93
April,	3.23	5.263	162.9	4.197	5.683	135.4	3.435	4.132	120.3	5.790	2.807	48.5	4.716	5.379	114.1	3.105	2.017	64.97
May,	3.56	2.119	59.5	2.763	2.031	73.5	3.702	2.482	67.0	0.956	2.487	260.2	1.579	1.987	125.8	1.836	0.917	49.95
June,	6.24	1.501	24.0	2.040	0.383	18.8	2.425	1.031	42.5	3.884	0.873	22.5	3.789	0.713	18.8	2.138	0.303	14.16
July,	3.57	0.573	16.0	9.134	0.326	3.6	2.951	0.360	12.2	2.971	0.229	7.7	3.933	0.281	7.1	6.273	0.315	5.02
August,	5.53	0.706	12.8	1.720	0.723	42.0	3.682	0.216	5.9	6.937	0.848	12.2	6.509	0.705	10.8	4.008	0.212	5.29
September,	3.43	0.358	10.4	4.614	0.318	6.9	0.323	0.103	31.9	1.291	0.277	21.5	1.878	0.243	12.9	1.603	0.138	8.64
October,	4.85	1.152	23.8	2.241	0.417	18.6	8.515	1.127	13.2	6.417	0.921	14.3	0.809	0.126	15.6	3.740	0.181	4.85
November,	4.83	2.248	46.5	5.764	1.878	32.6	5.803	2.447	42.2	7.024	2.922	41.6	2.682	0.355	13.2	1.785	0.354	19.85
December,	0.94	1.041	110.7	3.620	0.809	22.3	0.870	2.300	264.4	6.367	5.667	89.0	4.344	0.825	19.0	2.828	0.312	11.05
Totals and Averages,	45.49	20.418	45.9	49.563	23.908	48.2	44.018	25.487	57.9	57.931	30.487	52.6	41.419	18.775	45.3	38.177	12.182	31.91

Rainfall Received and Collected on the Sudbury River Water-shed—Continued.

Month.	1881. Rainfall.	1881. Rainfall Collected.	1881. Per Cent. Collected.	1882. Rainfall.	1882. Rainfall Collected.	1882. Per Cent. Collected.	1883. Rainfall.	1883. Rainfall Collected.	1883. Per Cent. Collected.	1884. Rainfall.	1884. Rainfall Collected.	1884. Per Cent. Collected.	1885. Rainfall.	1885. Rainfall Collected.	1885. Per Cent. Collected.	1886. Rainfall.	1886. Rainfall Collected.	1886. Per Cent. Collected.
	Inches	*Inches*		*Inches*	*Inches*		*Inches*	*Inches*		*Inches*	*Inches*		*Inches*	*Inches*		*Inches*	*Inches*	
January,	5.558	0.740	13.31	5.951	2.213	37.19	2.81	0.597	21.25	5.085	1.775	34.91	4.71	2.203	46.76	6.365	2.606	40.94
February,	4.646	2.491	53.62	4.546	3.872	85.18	3.865	1.661	43.05	6.545	4.742	72.45	3.865	2.182	56.44	6.28	7.734	123.16
March,	5.730	7.142	124.64	2.649	5.064	191.16	1.78	2.873	161.42	4.72	6.752	143.06	1.07	2.805	262.14	3.61	3.672	101.72
April,	2.000	2.669	133.44	1.824	1.497	82.09	1.845	2.330	126.27	4.405	4.925	111.82	3.605	3.133	86.91	2.225	3.361	151.06
May,	3.511	1.721	49.03	5.066	2.304	45.48	4.185	1.673	39.98	3.47	1.838	52.97	3.485	2.383	68.38	2.995	1.285	42.90
June,	5.395	2.309	42.80	1.664	0.913	54.87	2.401	0.518	21.58	3.445	0.719	20.86	2.865	0.735	25.66	1.465	0.350	23.93
July,	2.350	0.493	20.98	1.769	0.154	8.70	2.68	0.206	7.68	3.665	0.399	10.89	1.425	0.111	7.77	3.265	0.206	6.32
August,	1.358	0.264	19.45	1.667	0.099	5.91	0.735	0.140	19.06	4.65	0.458	9.85	7.185	0.429	5.97	4.10	0.168	4.09
September,	2.617	0.340	13.01	8.741	0.529	6.05	1.52	0.157	10.36	0.855	0.076	8.87	1.425	0.209	14.66	2.905	0.203	6.98
October,	2.955	0.331	11.20	2.074	0.534	25.74	5.60	0.331	5.92	2.48	0.148	5.98	5.095	0.599	11.75	3.235	0.260	8.01
November,	4.091	0.682	16.66	1.147	0.362	31.51	1.81	0.354	19.52	2.645	0.302	11.41	6.095	2.033	33.35	4.645	1.161	25.01
December,	3.958	1.383	34.93	2.296	0.561	24.45	3.55	0.345	9.72	5.17	1.650	31.91	2.72	2.091	76.99	4.975	1.819	36.56
Totals and Averages,	44.169	20.565	46.56	39.394	18.102	45.95	32.78	11.188	34.13	47.135	23.784	50.46	43.545	18.916	43.44	46.065	22.825	49.55

Rainfall Received and Collected on the Sudbury River Water-shed—Concluded.

Month.	1887.			1888.			1889.			1890.			Mean for 16 Years. 1875-1890.		
	Rainfall.	Rainfall Collected.	Per Cent. Collected.	Rainfall.	Rainfall Collected.	Per Cent. Collected.	Rainfall.	Rainfall Collected.	Per Cent. Collected.	Rainfall.	Rainfall Collected.	Per Cent. Collected.	Rainfall.	Rainfall Collected.	Per Cent. Collected.
	Inches.	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*		*Inches.*	*Inches.*	
January,	5.20	4.619	88.82	4.15	1.878	45.26	5.37	4.963	92.42	2.53	2.237	88.43	4.179	2.051	49.08
February,	4.78	4.558	95.35	3.685	3.255	88.32	1.655	1.926	116.39	3.505	2.464	70.29	4.062	3.176	78.19
March,	4.90	5.116	104.40	6.02	5.775	95.93	2.365	2.388	100.95	7.735	6.498	84.01	4.578	5.019	109.63
April,	4.265	4.522	106.03	2.425	4.566	188.30	3.41	2.434	71.37	2.645	3.236	122.35	3.320	3.622	109.10
May,	1.165	1.799	154.46	4.825	2.912	60.35	2.945	1.569	53.27	5.21	2.437	46.78	3.203	1.996	62.32
June,	2.65	0.714	26.93	2.535	0.728	28.70	2.80	1.128	40.27	2.03	0.980	48.27	2.985	0.869	29.11
July,	3.76	0.204	5.45	1.405	0.209	14.90	8.94	1.130	12.64	2.46	0.192	7.78	3.784	0.337	8.91
August,	5.28	0.382	7.24	6.225	0.677	10.87	4.175	2.554	61.18	3.865	0.235	6.08	4.227	0.552	13.06
September,	1.32	0.191	14.52	8.585	1.994	23.22	4.605	1.422	30.87	6.00	0.790	13.16	3.232	0.459	14.20
October,	2.835	0.339	11.96	4.99	3.566	71.45	4.255	2.194	51.57	10.51	4.053	38.56	4.413	1.017	23.05
November,	2.67	0.636	23.83	7.225	4.761	65.90	6.29	2.351	53.27	1.20	2.097	174.72	4.107	1.621	39.47
December,	3.88	1.147	29.58	5.395	5.428	100.60	3.14	3.997	127.30	5.31	1.779	33.49	3.710	1.947	52.48
Totals and Averages,	42.705	24.227	56.73	57.465	35.749	62.21	49.95	29.056	58.17	53.000	26.998	50.94	45.800	22.667	49.49

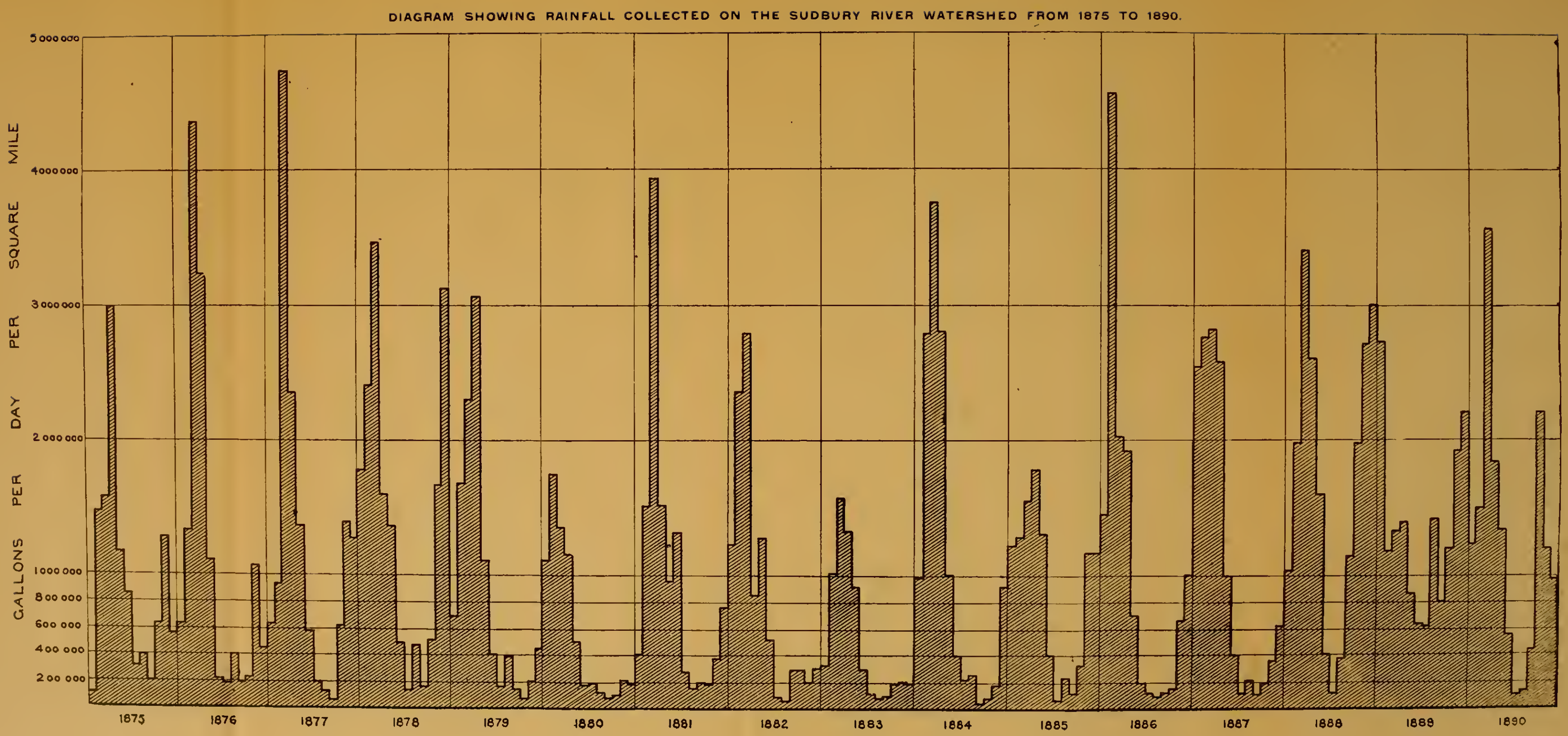


DIAGRAM SHOWING RAINFALL COLLECTED ON THE SUDBURY RIVER WATERSHED FROM 1875 TO 1890.
GALLONS PER DAY PER SQUARE MILE
5 000 000
4 000 000
3 000 000
2 000 000
1 000 000
800 000
600 000
400 000
200 000
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890

is the minimums recorded in the foregoing table which have the most value. These for periods varying in duration from one month to sixteen years have been carefully selected from the table, and are presented in more convenient form in the one which follows:—

Table showing the Average Daily Flow from the Sudbury River Water-shed for Different Periods, varying from One Month to Sixteen Years, selecting in each case the Dryest Period of the Given Duration.

Length of Period.	Dates.	Average Daily Flow of Water-shed. Gallons Per Day Per Square Mile.	Gallons Per Day Per Acre.	Cubic Feet Per Second Per Square Mile.
1 month,	September, 1884.	44,000	69	.068
2 months,	Sept. 1, 1884, to Oct. 31, 1884,	64,000	100	.099
3 months,	July 1, 1883, to Sept. 30, 1883,	85,000	133	.147
4 months,	July 1, 1883, to Oct. 31, 1883,	118,000	184	.183
5 months,	June 1, 1880, to Oct. 31, 1880,	131,000	205	.203
6 months,	June 1, 1880, to Nov. 30, 1880,	143,000	223	.221
7 months,	June 1, 1880, to Dec. 31, 1880,	147,000	230	.227
8 months,	June 1, 1880, to Jan. 31, 1881,	181,000	283	.280
9 months,	May 1, 1880, to Jan. 31, 1881,	219,000	342	.339
10 months,	April 1, 1880, to Jan. 31, 1881,	312,000	487	.483
11 months,	Mar. 1, 1880, to Jan. 31, 1881,	409,000	639	.633
1 year,	Mar. 1, 1880, to Feb. 28, 1881,	497,000	777	.769
2 years,	Feb. 1, 1882, to Jan. 31, 1884,	687,000	1,073	1.063
3 years,	Mar. 1, 1880, to Feb. 28, 1883,	764,000	1,194	1.182
4 years,	Feb. 1, 1880, to Jan. 31, 1884,	735,000	1,148	1.137
5 years,	Jan. 1, 1879, to Dec. 31, 1883,	769,000	1,202	1.190
6 years,	Oct. 1, 1879, to Sept. 30, 1885,	803,000	1,255	1.242
7 years,	Jan. 1, 1879, to Dec. 31, 1885,	839,000	1,311	1.298
8 years,	Jan. 1, 1879, to Dec. 31, 1886,	870,000	1,359	1.346
9 years,	Jan. 1, 1879, to Dec. 31, 1887,	902,000	1,409	1.396
10 years,	April 1, 1878, to Mar. 31, 1888,	944,000	1,475	1.461
11 years,	Jan. 1, 1875, to Dec. 31, 1885,	968,000	1,512	1.498
12 years,	Jan. 1, 1875, to Dec. 31, 1886,	978,000	1,528	1.513
13 years,	Jan. 1, 1875, to Dec. 31, 1887,	991,000	1,548	1.533
14 years,	Jan. 1, 1875, to Dec. 31, 1888,	1,042,000	1,628	1.612
15 years,	Jan. 1, 1875, to Dec. 31, 1889,	1,065,000	1,664	1.648
16 years,	Jan. 1, 1875, to Dec. 31, 1890,	1,079,000	1,686	1.670

With such a vast difierence in the average daily flow during the dryest month and the dryest year, and also in the flow during the dryest year and a long series of years, it is obvious that the quantity of water which can be made available from a given water-shed depends very much upon the amount which can be stored in seasons when water is abundant for use during seasons of drought.

A table will be presented subsequently to show directly the amount of storage required to make available different daily volumes of water per square mile of water-shed; but as this will take into account the effect of a greater or less amount of water surfaces in the water-shed, the relation of the evaporation from water surfaces to the rainfall upon them will be considered first.

The most valuable information upon the subject of evaporation is to be obtained from the paper presented by our past president, Mr. Desmond

FitzGerald,* to the American Society of Civil Engineers. His paper was based chiefly upon observations and experiments made at the Chestnut Hill Reservoir of the Boston Water-Works, and contains among other things, a mean evaporation for each month of an ordinary year. By comparing this with the mean rainfall the relation between the two can be established; and, as the evaporation does not vary much from year to year, we can also obtain approximately the relation between the evaporation and rainfall in a dry year by comparing the average evaporation with the rainfall in a dry year, like 1883.

The results of these comparisons are shown by the following table and diagram:—

Table showing Relation of Evaporation to Rainfall.

MONTH.	AVERAGE YEAR.			YEAR OF LOW RAINFALL.		
	Rainfall. Inches.	Evaporation. Inches.	Excess or Def'ncy of Rainfall. Inches.	Rainfall. Inches.	Evaporation. Inches.	Excess or Def'ncy of Rainfall. Inches.
January	4.18	0.98	+3.20	2.81	0.98	+1.83
February	4.06	1.01	+3.05	3.86	1.01	+2.85
March	4.58	1.45	+3.13	1.78	1.45	+0.33
April	3.32	2.39	+0.53	1.85	2.39	—0.54
May	3.20	3.82	−0.62	4.18	3.82	+0.36
June	2.99	5.34	—2.25	2.40	5.34	—2.94
July	3.78	6.21	—2.43	2.68	6.21	—3.53
August	4.23	5.97	—1.74	0.74	5.97	—5.23
September	3.23	4.86	—1.63	1.52	4.86	—3.34
October	4.41	3.47	+0.94	5.60	3.47	+2.13
November	4.11	2.24	+1.87	1.81	2.24	—0.43
December	3.71	1.38	+2.33	3.55	1.38	+2.17
	45.80	39.12	+6.68	32.78	39.12	—6.34

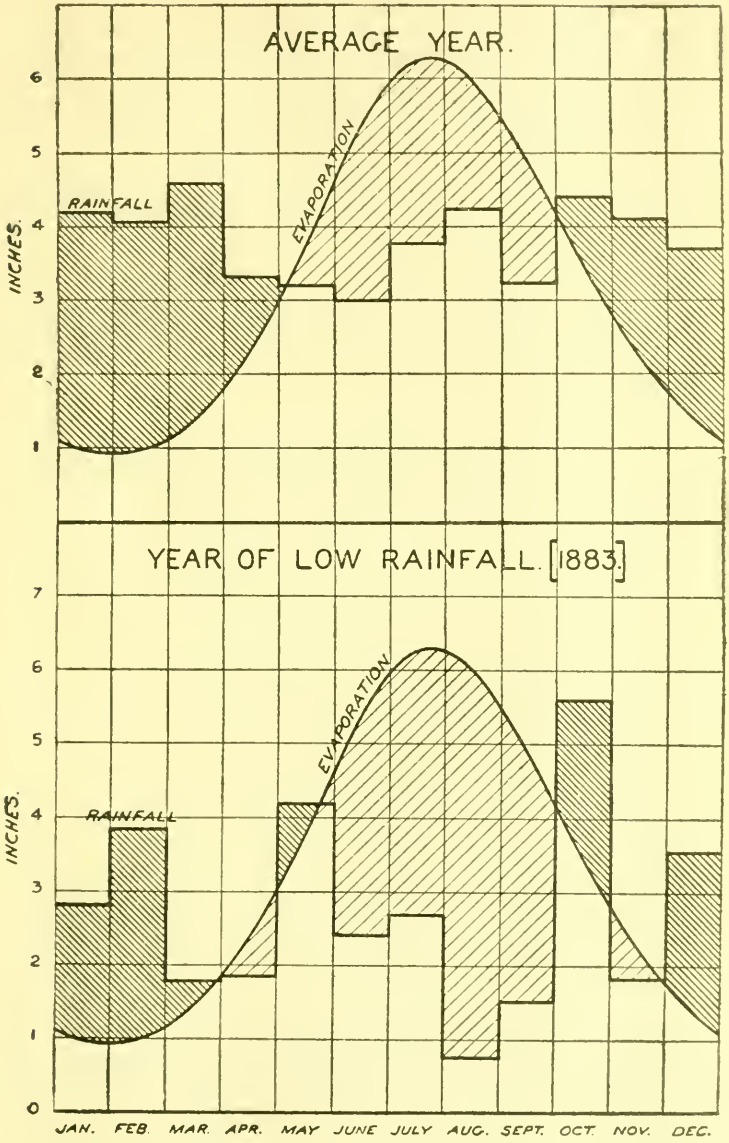
NOTE. + indicates excess of rainfall; — indicates deficiency.

It will be seen from the facts presented that the monthly rainfall varies much less during the year than the evaporation; also that in an average year the rainfall is 6.68 inches greater than the evaporation. The average year may be divided into two periods, one extending from May to September, inclusive, in which the evaporation is 8.77 inches greater than the rainfall; and the other extending from October to April, inclusive; in which the rainfall exceeds the evaporation by 15.45 inches.

In the year of low rainfall the evaporation was 6.34 inches greater than the rainfall. During the warmer months, from April to September, inclusive, the excess of evaporation was 15.22 inches, and during the other six months the rainfall was 8.88 inches in excess of the evaporation. These figures indicate that a pond will not lower by evaporation in a dry summer more than about fifteen inches, even if it receives no water from its water-shed.

* Evaporation, by Desmond FitzGerald, C. E., Transactions of the American Society of Civil Engineers, Vol. XV., 1886, p. 581.

Diagram showing the Relation of Evaporation to Rainfall.



NOTE.—The curved lines show the average evaporation in inches per month, and the horizontal lines the rainfall also in inches per month. The fine hatching indicates the excess of rainfall, and the coarser hatching the excess of evaporation.

The following table gives the quantity of water which may be made available per square mile of water-shed (estimating land surfaces only), with varying amounts of storage and a varying percentage of water surfaces. In preparing the table, the records of the flow of Sudbury River and of the rainfall upon the Sudbury River water-shed from 1875 to 1890, inclusive, as given in the table on pages 488-90, have been used; also the records of evaporation from water surfaces deduced from observations made at Chestnut Hill Reservoir during the years 1876 to 1880 and 1885 to 1887. For other years, when the evaporation was not measured, the average evaporation, as given in the table on page 492, has been used. The flow per square mile is in all cases the smallest recorded after taking into account the evaporation from water surfaces.

Table showing the Amount of Storage required to make available Different Daily Volumes of Water per square Mile of Water-shed (estimating land surfaces only) corrected for the Effect of Evaporation and Rainfall on Varying Percentages of Water Surfaces, not included in estimating the area of the Water-shed.

Daily Volume in Gallons per Square Mile of Land Surface.	Storage required in Gallons per Square Mile of Land Surface to prevent a Deficiency in the Season of Greatest Drought when the Daily Consumption is as indicated in the First Column, with the following Percentages of Water Surfaces.				
	0 Per Cent.	3 Per Cent.	6 Per Cent.	10 Per Cent.	25 Per Cent.
100,000	556,000	3,000,000	8,800,000	—	—
150,000	3,400,000	7,100,000	13,400,000	—	—
200,000	9,400,000	11,700,000	18,000,000	—	—
250,000	19,000,000	22,200,000	25,400,000	—	—
300,000	29,800,000	33,000,000	36,100,000	—	—
400,000	52,000,000	54,400,000	57,500,000	—	—
500,000	76,500,000	77,300,000	80,300,000	—	—
600,000	102,000,000	104,600,000	107,100,000	112,800,000	—
700,000	144,400,000	153,000,000	161,600,000	170,700,000	215,900,000
800,000	202,300,000	210,900,000	219,500,000	228,600,000	273,800,000
900,000	346,200,000	349,200,000	352,200,000	353,900,000	381,600,000
1,000,000	514,600,000	516,700,000	519,700,000	523,600,000	532,200,000

I will call particular attention to this table, because it contains in a convenient form for use all of the information with regard to minimum quantities which the Sudbury River records as published will furnish, and in addition it takes into account the effect of evaporation from varying percentages of water surfaces.

Having given the area of the water-shed, (land surface only), the area of water surfaces, and the available storage capacity, the yield of a source can be calculated in a few minutes with the aid of the table.

As an illustration of its use, let us assume that it is desired to know the yield of a pond having an area of .15 of a square mile and an available storage capacity of 225,000,000 gallons, which has draining into it 1.5 square miles of land surface. The amount of storage in this case would be equivalent to 150,000,000 gallons per square mile of land surface, and the water surface would equal ten per cent. of the land surface. By looking in the column of the table headed ten per cent. it will be seen that a storage of 150,000,000 gallons per square mile corresponds to a daily volume of between 600,000 and 700,000 gallons per square mile, or more exactly by proportion to 660,000 gallons, equal to 990,000 gallons daily for the whole water-shed. The results obtained by this method will in some cases be practically correct. In other cases it will be necessary to take account of local conditions, prominent among which may be leakage past a dam or filtration through the ground to lower levels; and the application of judgment will often be necessary to determine whether the water-shed under consideration will yield the same, or a greater or less amount per square mile than that of the Sudbury River. To aid in judging the relative yield of the water shed, it will be well to state the conditions which existed upon the Sudbury River water-shed during the time included in the records.

The area of the water shed from which the flow was measured was 77.764 square miles until the end of 1878, then 78.238 square miles until the end of 1880, and after that time 75.199 square miles. These areas include all water surfaces. From the beginning of the observations until the end of 1878, the water surfaces consisted of Farm Pond, Whitehall Pond (which was flowed in winter and drawn in summer), several mill ponds, and the various streams The areas of these combined water surfaces was equal to 1.02 per cent. of the land surfaces. The construction of artificial storage reservoirs has since increased the area of water surfaces. Three reservoirs were completed and filled in 1879, making the total area of water surfaces after this date, until 1886, 2.31 per cent. of the land surfaces. In 1886, Reservoir No. 4 was added, increasing the per cent. of water surfaces to 2.92. The dryest periods occurred between the years 1879 and 1886, and it may therfore be assumed that the water surfaces which had the most effect upon the present records were 2.31 per cent of the land area.

The flow of the river past the lowest dam has been greatly modified by the use of the artificial reservoirs; but this does not appear in the records, because the amount flowing past the dam is corrected by the amount added to or drawn from storage. The object in making these corrections has been to eliminate the effect of the reservoirs and to present in the records the natural flow of the stream modified only by such storage as is furnished by ordinary mill ponds and by Whitehall Pond. It cannot, however, be said that the effect of the reservoirs is wholly eliminated, because the evaporation from the increased water surfaces is not taken into account; and the dry weather flows recorded are consequently less than they would be if these reservoirs did not exist.

The average annual rainfall upon the Sudbury River water-shed is 45.8 inches, which is nearly the same as in the other parts of Massachu-

setts, so that, within the state, it is not often necessary to take account of differences in the amount of the rainfall.

The water-shed of the Sudbury River contains many hills with steep slopes, some of which are used for pasturage and others are covered with a small growth of wood. The valleys, as a rule, are not steep, and there are extensive areas of swampy land, generally covered with a growth of brush and trees. The hills are, for the most part, of rather impervious clayey material, containing boulders, while the flat land is sandy and in some cases gravelly.

The supply to be obtained from a given water-shed will not always be governed by the quantity of water which can be stored, because considerations of quality require that the levels of the reservoir should not be made to fluctuate too much, and that the reservoir should not be drawn below high water mark for too long a time.

The diagram given opposite has been prepared from the Sudbury River records to show the fluctuations of a reservoir from which 400,000, 600,000, 800,000 and 900,000 gallons of water per day per square mile are drawn. The dotted lines marked "overflow" represent the full reservoir. The shaded areas indicate a draught upon the reservoir, the amount of which in gallons of storage per square mile is shown on the diagram. It will be seen that a consumption of 800,000 or 900,000 gallons per day per square mile causes a reservoir to be drawn below high water mark for many years at a time, which could hardly be permitted except in the case of a pond with gravelly shores.

The only point remaining to be considered with regard to the quantity of surface water relates to the flow from water-sheds during short periods of extreme drought. The flow during such periods is chiefly of importance when it is desired to know the minimum flow of streams on which little or no storage can be obtained. On such water-sheds the water surfaces are generally insignificant, so that the Sudbury River records are not applicable unless they are corrected for evaporation. It is well known that the natural dry-weather flow of streams per *square mile* depends much upon the *extent* of the water-shed, because it is frequently observed that streams draining but a small area dry up in summer, while those draining large areas continue to flow, though with a greatly reduced volume. There is also a large variation in the dry weather flow from water-sheds of the same size due to the amount of water stored in the ground and subsequently coming out in the form of springs. The records of the natural flow of streams in a very dry period are very meagre. The lowest flow of the Sudbury River occurred during the month of September, 1884, and averaged only 44,000 gallons daily per square mile of water-shed. Correcting for the excess of evaporation from water surfaces over the rainfall upon them, we obtain 97,000* gallons per square mile as the amount that

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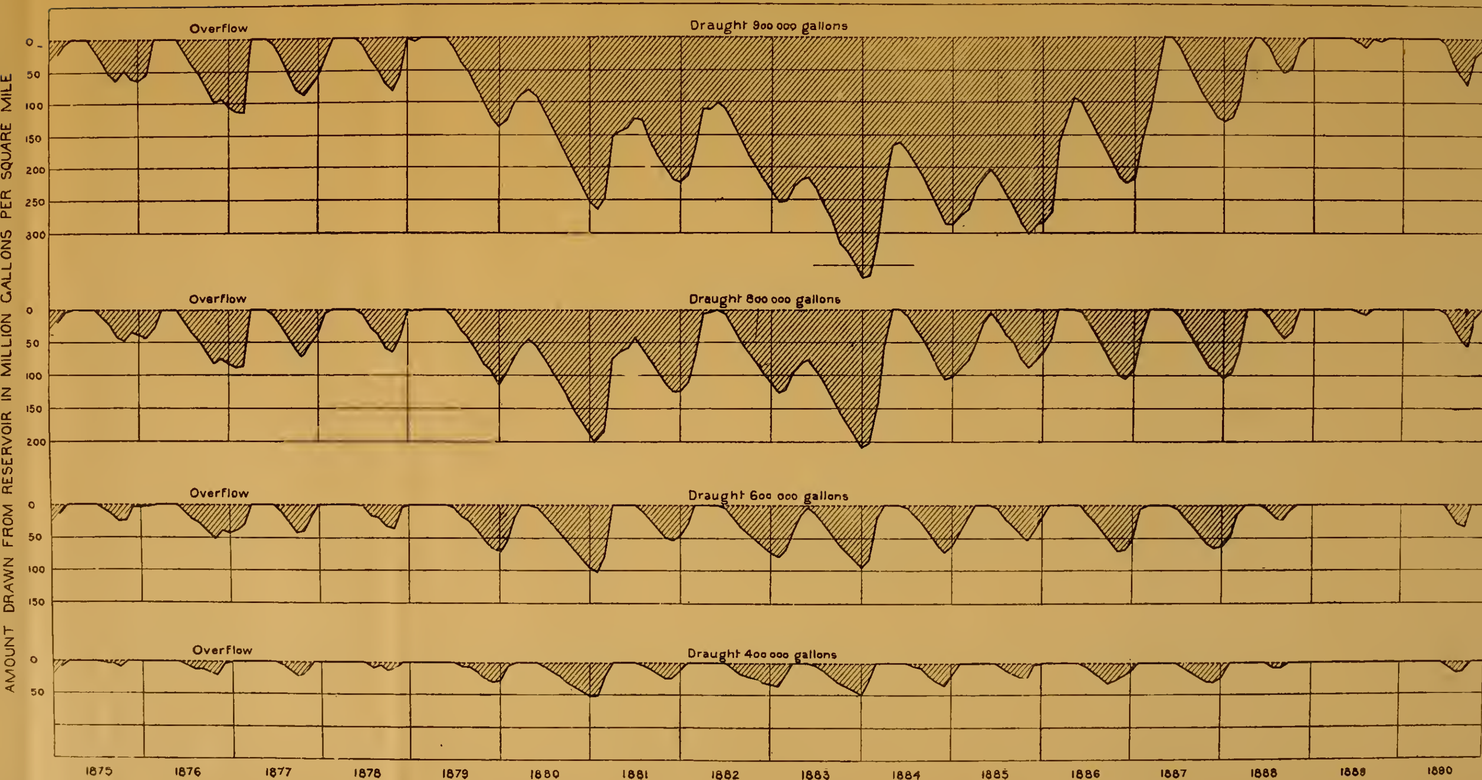
*This quantity is somewhat larger than it should be as no account is taken of the water which came from the ground adjoining the reservoirs as they were being drawn down to supply the city.

DIAGRAM SHOWING THE FLUCTUATIONS OF A RESERVOIR CAUSED BY A DAILY DRAUGHT OF 400,000, 600,000, 800,000, AND 900,000 GALLONS PER DAY PER SQUARE MILE OF WATERSHED.



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the flow would have been if there had been no water surfaces. The next lowest monthly record was in September, 1877, 60,000 gallons per square mile. At this date the reservoirs had not been constructed and the area of water surfaces to which the corrections for evaporation should be applied was smaller. Making the correction we have as the flow per square mile, 82,000 gallons per day.

In the report of the Water Commissioners of the Pittsfield Fire District, dated April 1, 1887, it is stated that on September 10, 1886, at the end of a somewhat extended drought, it was found by a careful measurement that 446,000 gallons were flowing daily in Sackett Brook and in Ashley Brook below the Ashley Reservoir, at a time when no water was overflowing from the reservoir. The area from which this water flowed is found by measurement from the topographical map of the State to be 5.3 square miles: consequently the flow equals 84,000 gallons per square mile. This drainage area is mountainous, and contains no water surfaces except the streams.

In the report of the Board of Water Commissioners of Northampton for the year ending Feb. 1, 1883, a measurement of Roberts' Meadow Brook in August, 1882, is recorded. The volume, when the stream was at its lowest point, was 450,000 gallons in twenty four hours. The area of the water-shed is 10.6 square miles; hence the flow per square mile amounted to 42,000 gallons per day. This water-shed has steep slopes, and contains no ponds or reservoirs of any importance.

On Aug. 8, 1890, I measured the flow of Beaver Dam Brook, one of the feeders of Lake Cochituate, and found the volume of water flowing to be 221,000 gallons per day. The measurement was made at the point where the brook first crosses the road between Natick and South Framingham. The area of the water-shed of the brook above this point, as taken from the topographical map of Massachusetts is 5.82 square miles, making the daily flow per square mile 38,000 gallons. This water-shed contains Waushakum Pond, which has an area of 87 acres and a very large area of meadow and swampy land.

It should be remarked with reference to the figures which have been given that the Sudbury River records represent the average flow for a month, while the other measurements represent the flow at one time only. On the other hand the Sudbury River measurements represent the dryest periods occurring in sixteen years, while the other measurements, although taken at times of very low flow, do not probably represent the dryest periods which occurred.

Judging from the few measurements which are available it seems fair to infer that the minimum flow from a square mile of water-shed without storage will not, under favorable conditions, exceed 80,000 gallons daily; and that under conditions frequently met with the flow may not be more than half of this amount; or with very small water-sheds it may be nothing at all, as in the case already cited of streams which run dry in summer. These statements do not, however, apply to the larger streams in Massachusetts, such as the Connecticut, Merrimack and Chicopee rivers, which have a larger minimum flow.

Quantity of Ground Water.

It has already been stated that ground water supplies are much more limited as regards quantity than surface waters, and that the amount to be obtained at any given place cannot be as accurately predicted. There are, however, many examples in Massachusetts which show that the towns and smaller cities can obtain a sufficient supply of ground water where the local conditions are favorable; for instance, the city of Newton, with a population in 1890 of 24,379, obtains a ground water supply, and has recently been extending its works with a view to supplying a much larger population.

The statement that the quantity of ground water cannot be as accurately predicted as the quantity of surface water should not lead to the inference that the quantity of ground water to be obtained from any given source is chiefly a matter of guesswork, because it is feasible in most cases as a result of experience and calculation to determine with a moderate degree of accuracy the quantity of ground water which can be obtained from a given source.

In the case of ground waters as in the case of surface waters the supply is dependent upon the rainfall. It may be the rain which falls in the vicinity of the source and filters directly through the ground to it, or it may be that which finds its way into the streams and then filters through the bottom of the stream into the ground near the source from which the supply is taken; but it rarely happens that the supply comes from the rain which falls far outside of the direct water-shed of the source or of the stream near it.

In a large majority of cases ground water supplies are taken from large wells, tubular wells, filter-galleries or filter-basins situated in the low lands adjacent to some large stream or pond. There are many instances, however, in which the supply is taken from a locality where no water comes by filtration from a stream or pond, and the whole supply is consequently rain water which filters into and through the ground to the point from which the water is taken. These two classes of ground waters require a somewhat different consideration; and the latter, in which a supply is taken from what may be called the direct water-shed of the well,* will be considered first.

In this case the conditions are in some respects similar to those which obtain in the case of surface water supplies; that is, the size of the water-shed, the proportion of the rainfall which will filter into the ground, and the amount of available storage in the interstices of the ground in the vicinity of the well are important factors; and there is in addition a factor which does not appear as prominently in the case of surface water supplies, namely, the porosity of the ground.

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*For convenience the term "well" will be used to designate all kinds of constructions for obtaining water from the ground.

Statistics regarding the proportion of the rainfall which will filter into the ground are very few, but it is obvious that much less will enter the ground where the surface is sloping and nearly impervious than where it is flat and porous. Probably the most favorable water-shed which can be obtained is one which is generally level and gravelly and contains numerous depressions having no outlet, so that all the water from the rainfall which is not lost by evaporation goes of necessity into the ground. Much of the water-shed of the Mansfield source of supply is of this character. Under these most favorable conditions it seems probable that the quantity of water which passes into the ground will not vary much from that which flows over the surface and underground from the same area of water-shed into a stream. We may, therefore, for the present, estimate that the quantity of water which can be collected from the water-shed of a ground water source will not in any case *exceed* the amount to be collected from an equal area of water-shed of a surface water source, and that generally it will be less by the amount which runs off over the surface.

There is a common tendency to over-estimate the quantity of water which can be obtained from the ground in a locality where nature has already provided a free flowing spring, or where flowing test wells have been driven; but estimates based upon the size of the water-shed draining toward the spring or well will often show how incorrect these estimates are.

Although a sufficient water-shed is essential, it is equally essential that the ground should be porous enough to permit the required quantity of water to flow from the ground into the well.

In many cases where the supply required is not very large sufficient information as to the porosity of the ground can be obtained by driving test wells and determining the character of the strata penetrated. Some additional information may also be obtained by pumping from these wells with a hand pump. In order to predict the quantity of water which will flow into a well, after the character of the material is known, it is necessary to depend upon the experience obtained from existing wells in similar situations. Some information bearing upon this subject is given in the table opposite page 502.

In cases where a larger supply is necessary, or where the results of the tests above mentioned are not sufficiently definite, it may become desirable to make a more complete test, which is generally done by driving a large number of test wells, connecting them all with a single suction pipe and pumping from them.

A test of this character is generally intended to show not only the porosity of the ground, but also to indicate the amount of storage which is available, and the distance from which the ground water may be drawn to the wells when the water in the vicinity is lowered by long-continued pumping in a dry time. Records are kept of the height of the ground water in the immediate vicinity of the test wells and for a considerable distance from them in all directions. For this purpose frequent observations are made of the level of the water in existing wells which may be

affected by the pumping, and where these do not exist in sufficient number additional test wells are driven to give access to the ground water.

A test of this kind should be made during as dry a period as possible; but even then the quantity pumped is not necessarily the safe capacity of the source, and the test has its greatest value in the opportunity it affords the engineer of determining the storage capacity of the ground, and the extent of the area from which the rainfall may be expected to filter toward the well. With the information obtained by such a test made in the dryer portion of an ordinary year it is feasible to estimate with a moderate degree of accuracy the safe capacity of a source in a dry year. A test of this character, lasting three months, was made at Eaton's Meadows, Malden, in 1887-88, before constructing the permanent works at that place.

It is sometimes feasible in the case of a proposed ground water supply to determine whether the source is worthy of careful investigation by means of the table given on page 492, for determining the volume of surface water obtainable with different amounts of storage. If, for instance, it is desired to obtain a supply of 300,000 gallons per day, and the watershed draining toward the proposed well is one square mile, we find that in the case of a surface water supply the storage, when there are no water surfaces, must be 29,800,000 gallons. If the supply is to be taken from the ground it seems fair to assume that at least an equal amount of storage will be required; and the question to be considered relates to the probability of obtaining this amount of available storage, which is equivalent to the contents of a pond having an area of ten acres and a depth of nine feet. Porous gravel or sand when saturated contains in the neighborhood of thirty-five per cent. of water, but of this a portion remains after the ground is drained, so that only about twenty-five per cent. of the whole mass will run out when the water table is lowered. Therefore, in order to obtain 300,000 gallons daily from a square mile during the dryest period, it is necessary to have a storage equivalent to that furnished by forty acres of porous gravel in which the water table can be lowered nine feet. A superficial examination of the ground may show whether it is probable that this amount of storage can be obtained, and in this way indicate whether it is desirable to make further investigations.

In the case of wells located near a large stream or pond there is always a direct water-shed, the yield from which is to be obtained by the methods already indicated; but if this does not supply a sufficient quantity of water a greater or less amount will also filter from the stream or pond as soon as the adjacent ground water is lowered below the level of the surface water. That much water may come from a stream or pond and still have the characteristics of ground water is definitely shown in the case of the filter-gallery near Horn Pond, in Woburn, where the pond contains an abnormal amount of chlorine, *owing to the tannery drainage

*The normal chlorine of the region, is 0.33; the average chlorines of the filter-gallery and pond for three and one-half years are, respectively, 2.20 and 2.57.

which contains much salt; and the filter-gallery water also has an abnormal amount of chlorine which cannot be attributed to any other source than the pond. There are many other instances in the State where there are strong indications that a large portion of the supply comes from the neighboring river or pond, showing that the Woburn case is not an exceptional one.

No definite figures have been obtained of the amount of water which will filter through river or pond bottons, but it is known that they get silted up so that the amount of water which will pass through per square foot is small, and it is consequently necessary to have a large area of river or pond bottom in the vicinity of the ground water source to obtain a large amount of water by this kind of filtration.

With regard to the form of construction used, it may be said that no one method is applicable to all cases. Where the material is coarse and porous within a short distance of the surface and the quantity of water required is not very large, a circular well covered to exclude the light is generally the best. In other instances, where the material for a long distance from the surface is impervious, but is underlaid with pervious material, it is impracticable to excavate a large well to the required depth, and it becomes necessary to sink tubular wells down to the porus stratum which may sometimes be found overlying the solid rock. An instance of this kind is found at Malden where the average depth of the wells is sixty-five feet. There are also other instances in which driven wells are used to obtain water from a larger territory than would be influenced by a single large well.

Tubular wells may be connected by means of a large suction-pipe directly with the pump, which is generally the cheaper form of construction, or they may be connected with excavated wells or filter-galleries, into which the water from the driven wells will flow.

Filter-galleries are built in some instances where it is desired to intercept the ground water from a greater extent of territory than will be influenced by a single well. They are in fact elongated wells, except that, in practice, on account of the cost, they are not usually sunk to as great a depth.

Filter-basins perform the same office in collecting water as wells and filter-galleries, but being uncovered, the water in them deteriorates, owing to the rapid growth of vegetable and animal forms which flourish in this kind of water when the light is not excluded. This form of construction should therefore be avoided.

There are many instances in which the main supply comes from wells and filter-galleries, but is increased by means of driven wells extending from them into porous strata at lower levels.

In addition to the ordinary driven wells already referred to, which are limited in depth to from thirty to ninety feet, and do not in any case penetrate the rock, attempts have been made in several parts of Massachusetts to obtain a large supply of water by sinking wells six or eight inches in diameter into the rock to a depth of several hundred or even several thousand feet. The result has been in nearly every case unsatisfactory, and in no

way comparable with the results obtained from comparatively shallow wells in porous material.*

The information heretofore published with regard to the quantity of water which can be obtained from wells and filter-galleries variously situated is very meagre. With a view of obtaining additional light upon this subject a circular has been sent to the places in Massachusetts having a ground water supply, asking for information with regard to the character of the works constructed for obtaining water, the nature of the ground, and the capacity of the source. Replies to the circular were received from 35 places, and the information thus obtained is given in a condensed form in the table opposite.

The areas of water-sheds in columns 6 and 7 were obtained in most cases by sketching upon the topographical map of the State the outlines of the water-sheds and measuring the included area. In the case of the direct water-sheds (column 6), the results are for the most part only rough approximations, particularly those marked with an asterisk. The estimated capacities of sources as given in columns 13 and 14 were furnished by those connected with the various water works.

Before reviewing the tabulated information, it may be well to call attention to the fact that comparatively few of the ground water supplies have been subjected to a severe test in a dry year like 1880 or 1883, because a large number of them were constructed since that time; and of those constructed at an earlier period the greater number had then been in use so short a time that the draught upon the works was not excessive.

The average yield of the Sudbury River water-shed per square mile during the year 1880 was 580,000 gallons per day and for the four years ending in 1883, 738,000 gallons. In contrast with this we have as the yield in 1887 (the dryest of the four years ending in 1890), 1,154,000 gallons per day per square mile, and as the average yield for the whole four years, 1,381,000 gallons. These figures, showing that the yield of water-sheds during the last four years, has been very nearly twice as large as during the dry period of four years ending in 1883, make it evident that records and estimates obtained from sources which are being used nearly up to their full capacity in these comparatively wet seasons will tend to show that the sources will furnish more water than they can be depended upon to furnish during a prolonged drought. In other cases where only a small part of the capacity of the works is now being used, it is obvious that the pumping records are of value only as showing that the sources will yield at least the amount given; but they do not in any way indicate the maximum capacity of the sources. The table must be used with discretion, but it is believed that when so used it will be of considerable value to those selecting sources of ground water supply.

The table represents so much variation in conditions and in value of data that it is hardly feasible to make any summary of it. It may be well, however, to call attention to a few prominent features.

* Statistics of deep wells sunk in rock are given in a table on pp. 26, 27 of the Fourteenth Annual Report of the Water Commissioners of Taunton, Mass., Nov. 30, 1889.

STATISTICS REGARDING THE CAPACITY OF PUBLIC WATER SUPPLIES TAKEN FROM THE GROUND.

1	2	3	4	5	6	7	8	INFORMATION REGARDING CAPACITY OF SOURCE.						15
								Pumping Records.				Estimated Capacities.		
CITY OR TOWN.	Population in 1890	Date of Construction	DESCRIPTION OF WORKS	Adjacent Stream or Pond	Approximate Area of Direct Water-shed of Well or Filter-gallery. Square Miles	Area of Water-shed of stream or pond near Ground-water Source. Square Miles	Character of the Ground in which Works were built.	9 Maximum Year. Gallons per Day.	10 Maximum Month. Gallons per Day.	11 Maximum Week. Gallons per Day.	12 Maximum Day. Gallons per Day.	13 Dry Season. Gallons per Day.	14 When Ground is Filled with Water. Galls. per Day.	REMARKS.
Amesbury (original source)	9,798	1885	Well 20 feet in diameter and 50 feet deep, thirty-six 2-inch tubular wells 45 feet deep.	Very small stream	—	—	Clay, gravel at bottom.	—	—	—	—	100,000		No pumping records. Source would not furnish over 80,000 or 100,000 gallons per day, and was abandoned.
Amesbury (new source)		1886	Two open basins each about 80 x 40 feet. The basin from which most of the water is taken is 14 feet deep, and has fourteen 2-inch tubular wells extending 16 feet below its bottom.	None.	—	—	Gravel and some clay.	—	—		—	400,000	—	No pumping records. Average consumption about 175,000 gallons per day.
Attleborough	[illegible]	1872 / 1882	Well 13 feet in diameter, bottom 5 or 6 feet below bottom of river, filter-gallery 3 feet wide, 3 feet high and 10 feet long, five 2-inch, two 1¼ inch, and one 3-inch tubular wells driven in well and gallery 34 feet below bottom of well.	Ten Mile River.	—	21.10	Loam, gravel, quicksand, and at bottom gravel.	—	—		—	200,000 to 300,000	200,000 to 300,000	No pumping records. An additional supply is contemplated.
Ayer	[illegible]	1887	Well 25 feet in diameter at bottom, 27 feet deep.	Large Mill Pond.	—	4.74	Gravelly 18.7 feet, then rock.	62,262	85,780		—	—	—	Soon after the works were constructed the capacity was estimated at 10,000 gallons per hour, equal to 240,000 gallons per day.
Bradford	3,720	1890	Eight wells on Porter's Island, in the Merrimack River, about 100 feet from the shore; three of them 12 feet square, and five 12 x 24 feet, all 20 feet deep.	Merrimack River.	—	4,819 0	About 16 feet of river silt, then 1 to 4 feet of gravel, then clay.	—	—		—	250,000	300,000 to 400,000	No pumping records. About 250,000 gallons per day were pumped in the summer of 1891. Three additional wells are being built.
Braintree	4,848	1887	Filter-gallery 110 feet long, 15 feet wide and 13.5 feet high, bottom 16 feet below high water in Little Pond.	Little Pond.	0.12	0.55	Coarse, porous gravel.	213,079	301,801	—	557,287	—	—	
Bridgewater, East Bridgewater	4,249 / [illegible]	1888 / 1889 / 1890	Two wells built first, one 6 x 20 and 17 feet deep, the other 20 feet in diameter and 18 feet deep. The third well, built in 1889, is 10 feet in diameter and 33 feet deep. In the bottom of this is a 6-inch tubular well 86.5 feet deep. The fourth well is tubular, 202 feet deep, sunk in 1890. Water is also drawn from a spring near the wells.	Town River.	0.32*	55.[illegible]2	About 15 feet of clay, then 3 feet of gravel, then ledge.	[illegible]4,263	131,775	161,543	173,14[illegible]	—	—	Wells to furnish an additional supply are contemplated.
Brookline (excluding extension)	12,10[illegible]	1875	Filter-gallery in two sections, 491 and 571 feet long, connected by a conduit 80 feet long. From 4 to 6 feet in width and height.	Charles River.		134 20	Gravel and coarse sand.	863,509	1,258,990	—		750,000	—	
Brookline (including extension)		1875 / 1890	The extension made in 1890 consists of forty-four 2½-inch tubular wells averaging 35 feet in depth, included in a length of about 2,500 feet.	Charles River.	—	1[illegible]4 .0	Tubular wells sunk through about 25 feet of peat, muck and quicksand into porous gravel.	964,873	1,25[illegible],[illegible]99	1,436,137	1,829,680	1,500,000	4,000 000	
Canton	[illegible] 38	1889	Well 40 feet in diameter and 25 feet deep, twelve 2-inch tubular wells in the vicinity are connected by siphon.	Beaver Brook.	0.24*	2.47	Close clayey gravel, very hard at bottom.	79,100	—	143,126	224,136	25[illegible],000	[illegible]0,000	The 224,136 gallons were obtained by pumping out practically all of the water in the well.
Cohasset	[illegible]348	1886	Sixty-one tubular wells, each 2 inches in diameter and 30 to 40 feet deep, included in an area 125 feet long and 90 feet wide.	Small Brook.		0 42	Sixteen to 25 feet of muck, clay, sand, and blue clay, then gravel at bottom.	61,974	114,708	160 507	346,15[illegible]	—	[illegible]50,000	
Dedham	[illegible],123	1881	Well 26 feet in diameter, 18 feet deep, situated 40 feet from the river.	Charles River.	0.15*	104 01	Sand and coarse gravel.	224,814	[illegible]6,567	400,843	[illegible]4,240	900,000	1,[illegible]00,000	
Easton	4,493	1887	Well 29 feet in diameter at the top and 27 feet at the bottom, 26 feet deep.	Queset River.	0.11*	4.22	Clayey gravel.	101,771	125,367	161,233	248,600	—	—	A small storage reservoir has been constructed in the valley just above the well.
Framingham	9,239	18[illegible]	Filter-gallery at edge of pond 4[illegible]0 feet long, 3½ to 4 feet wide and 4 feet high, bottom of gallery 6 feet below surface of pond.	Farm Pond.	0.10	—	Coarse and fine sand.	239,248	418,055	496,735	578,397	1,000,000	1,000,000	Supplies only South Framingham and a portion of Framingham Centre.
Franklin	4,831	1884 / 1887	Two wells, one 20 feet in diameter and 25 feet deep, the other 33 feet in diameter and 18 feet deep.	Mine Brook.	—	7.6[illegible]	Gravel for 8 feet, then ledge.	90,575	140,630	—	253,800	300,000	600,000	
Grafton	[illegible]00[illegible]	1886	Filter-gallery 95 feet long, 12 feet wide and 17 feet high, bottom is 20 feet below surface of ground.	Quinsigamond River.	—	35.05	Three feet of peat, below that blue gravel to bottom of gallery, then ledge.	—	—	—	138,000	—	1,000 000	An artesian well 6 inches in diameter and 97 feet deep was sunk 1889, but not connected with the works until July, 1891.
Hopkinton	4,[illegible]88	1884	Three tubular wells each 6 inches in diameter, 50, 65 and 75 feet deep, near summit of a large hill. Wells included in a distance of 260 feet.	None.	Very small	—	From 3½ to 18 feet of clay and gravel, then rock broken by seams.	Estimated 4[illegible],000	—	Estimated 60,000	Estimated 70,000	40,000	125,000	An 8-inch well, 119 feet deep, has been added, but is not included in making these estimates.
Hyde Park, Milton	10,193 / 4,278	1885	One hundred and thirty-two 2-inch tubular wells 34 to 38 feet deep included in an area about 1,000 feet long and 150 feet wide.	Neponset River.	0.4[illegible]*	94 80	Porous gravel.	437,534	610,000	800,000	910,800	—		
Kingston	1,659	1886 / 1888	Well 20 feet in diameter. Filter gallery 360 feet long, 20 inches wide and 14 inches high.	Jones River.	—	22.24	— —	—	—	—	—	—	17[illegible],000	
Lexington	3,197	1884	Four large wells, also 8-inch tubular well 190 feet deep, all but 14 feet in rock.	Vine Brook.	Very small.	0 60	Wells sunk through peat and hard pan into rock.	Estimated 90,000	—	—	—	—	—	In a dry time a part of the supply has to be taken from supplementary sources.
Malden	23,[illegible]31	1889	Fifty-one 2-inch tubular wells sunk to an average depth of 65 feet included in an area 100 by 300 feet.	None.	1.61†	—	Wells sunk through peat, clay and compact sand, averaging 55 to 65 feet in depth, into porous gravel.	747,446	940,403	1,041,881	1,17[illegible] [illegible]92	500,000	1,200,000	There is an additional area of watershed of 1.5 square miles, which is possibly tributary to the wells under certain conditions.

* Very rough approximation.

† The area contributing to this source varies with the amount of water pumped. The figure given is an engineer's estimate of the area tributary to the wells under normal conditions.

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STATISTICS REGARDING THE CAPACITY OF PUBLIC WATER SUPPLIES TAKEN FROM THE GROUND.

1	2	3	4	5	6	7	8	INFORMATION REGARDING CAPACITY OF SOURCE.						15
								Pumping Records.				Estimated Capacities.		
								9	10	11	22	13	14	
CITY OR TOWN	Population in 1890.	Date of Construction	DESCRIPTION OF WORKS.	Adjacent Stream or Pond	Approximate Area of Direct Water-shed of Well or Filter-gallery. Square Miles.	Area of Water-shed of stream or pond near Ground-water Source. Square Miles.	Character of the Ground in which Works were Built.	Maximum Year. Gallons per Day	Maximum Month. Gallons per Day	Maximum Week. Gallons per Day	Maximum Day Gallons per Day.	Dry Season. Gallons per Day.	When Ground is Filled with Water. Galls. per Day.	REMARKS
Mansfield,	3,432	1888	Well [illegible] feet in diameter and 20 feet deep 625 feet from the river,	Canoe River,	—	4 35	Porous gravel	157,968	170,[illegible]	—	305,170	—	—	The maximum day's pumping lowered the water in the well 4 5 feet. The amount pumped during construction in a very wet season was estimated at 3 000,000 gallons.
Middleborough	6,065	1886	Well 26 feet in diameter and [illegible] feet deep, 100 feet from the river,	Nemasket River,	—	6 9[illegible]	Coarse, loose gravel,	142,730	205,9[illegible]	247,428	351,000	1,000,000	2,000,000	In July, 1888, when the stand-pipe was shut off for ten days, and continuous direct pumping was resorted to, about 500,000 gallons were pumped daily and the ground water lowered but little more than a foot.
Newburyport	13,947	1881	Two wells, one [illegible] feet diameter and 15 feet deep, the other is smaller. A small storage reservoir fed by springs is near the wells.	Merrimack River,	—	—	Porous gravel,	443,047	[illegible]03 8[illegible]8	501 490	649,350	—	—	
Newton (excluding extension made in 1890)	24,379	1876 / 1886	Filter basin 1, 75 feet long, 10 feet wide at bottom, 8 to 75 feet wide at high-water mark, bottom 10 feet below water in river. Eight tubular wells in bottom of basin, 1½ to 4 inches in diameter, also four [illegible]-inch and four 4-inch tubular wells on opposite side of river.	Charles River,	—	14 . 0	Filter-basin in fine gravel, sand and quicksand. Tubular wells sunk to coarse sand or gravel.	918 013	1,218,387	—	1 747,000	1,[illegible]50,000	—	These works in 1880 furnished 1, 50,000 gallons per day after pumping for six weeks in very dry weather
Newton (including extension made in 1890).		1876 / 1886 / 1890	The extension made in 1890 consists of one hundred and seventy-four 2½-inch tubular wells from 21 to [illegible]0 feet deep, connected with a wooden conduit 2,952 feet long and 4 feet square in section. [illegible]2 feet of this conduit replace an equal length of filter-basin	Charles River,	—	140 50	The 174 2½-inch wells are sunk in material varying from porous gravel or coarse sand to quicksand or hard pan.	1,041,610	1 400 419	1,0[illegible]9 2[illegible]5	—	2,000,00	6 000,000 to 8,000 00	
North Attleborough,	6,727	1884	Well 30 feet in diameter and 26 feet deep 470 feet from Whiting's mill-pond,	Whiting's Mill Pond on Ten Mile River	—	4 3	Through quicksand to gravel,	166,575	—	330 [illegible]	155,0 0	500,0 0	—	
Revere, Winthrop.	5,668 / 726	1884	One well 3[illegible] feet in diameter, [illegible]0 feet deep, with three 6-inch and two 2-inch tubular wells in the bottom. Another well 40 feet in diameter and [illegible] feet deep, with one 8-foot well, 30 feet deep, and eight [illegible]-inch tubular wells in bottom. Also one hundred 2-inch tubular wells in the vicinity, comprised in a triangle whose sides are 1,100, 1,300 and [illegible]5[illegible] feet in length.	Small stream,	0.78‡	0 67	Through clay to gravel which is reached at from 50 to 75 feet beneath the surface.	465,191	680,411	726 210	1,006,395	560,000	2,600,000	The estimated yield of this source in a dry season (560,000 gallons) is a little less than the amount actually pumped in August, 1891. So large a draught, however, could not be continued during the whole of an ordinary year without exhausting the supply.
Stoughton,	1,[illegible]52	1886	Well [illegible] feet in diameter and 30 feet deep,	None,	0 23*	—	Ledge, except near the surface of the ground.	—	—	—	—	—	—	Average daily consumption, estimated at 50,000 gallons per day, requires about all of the water that the well will supply
Swampscott / Nahant	[illegible] 108 / 880	188[illegible]	Well 22 feet in diameter and [illegible]0 feet deep, 35 feet from brook, with six 2-inch tubular wells in bottom, driven [illegible]0 to 75 feet. Supplementary supply from seventy-two driven wells about 40 feet deep, near the brook above the large well.	Stacy's Brook,		2 62	Loam at surface, then blue clay from [illegible] to 28 feet, with coarse gravel beneath.	2·4 [illegible]53	91,7[illegible]8	645,[illegible]43	1,015,050	400,000 to 600 000	1 200,[illegible]0[illegible]	A large portion of the water of Stacy's Brook is diverted into the Lynn intercepting sewer.
Taunton	25,448	1876	Filter-basin 40[illegible] feet long, 17 feet wide at bottom, bottom 8 feet below low water in river. Filter-gallery [illegible]63 feet long, [illegible] feet 2 inches in height, 4 feet in width, bottom level with filter basin. Two tubular wells sunk in bottom 2[illegible] to 37 feet deep. Filter-bank 94.6 feet long, 40 feet wide at bottom, 10 feet high	Taunton River,		[illegible]1[illegible].40	Boring at west end of basin showed 10 feet of sandy gravel, 10 feet of sand mixed with clay, 20 feet of clay, 10 feet of clay mixed with fine gravel, 2 feet of fine gravel, 35 feet very hard blue clay, with granitic sandstone beneath.	918 1[illegible]	1,14[illegible],6[illegible]6	1,21[illegible],358	1, [illegible]63,738	1,000 000	[illegible], 00,000	There is a direct connection with Taunton River, and this water is used when the supply is insufficient. It is estimated that during the days of maximum consumption from one-third to one-half of the water pumped is drawn from the river.
Tisbury,	1,[illegible]50	1887	Filter gallery 38 feet long, 7 feet wide at bottom, 10 feet high.	Lake Tashmoo,		—	Sand,	—	—	—	—	—	—	The gallery can be pumped out in three hours with a pump having a capacity of 1,0.0,000 gallons in 24 hours, and will fill again in about 45 minutes.
Waltham	18,707	1873	Filter-basin of irregular shape, having an area of about one-fourth of an acre. Bottom is 8 5 feet below the average level of water in the river.	Charles River,	1 11§	181 00	Porous gravel,	687 749	[illegible]43,[illegible]7	1,[illegible]43 469	1,518,200	1,100,[illegible]0	—	Works are now being built to increase the supply of water
Ware	7,329	1886	Well 26 feet in diameter, and 22 feet deep,	Muddy Brook,	[illegible].37*	19.44	12 feet of clay, then coarse gravel,	179,676	260 040	292,449	462,900	864,000	1,0[illegible]0,000	
Watertown / Belmont	7 073 / 2,098	1885 / 1889 / 1890	Filter-gallery in three sections, 90 feet long, 15 feet wide, 175 feet long, 5 feet wide, and 2 feet high, 102 feet long and 8 feet wide. The last is at right angles to the other two, and all are on a level. In 1889, twenty 2-inch tubular wells were added. In December, 1890, a well 20 feet in diameter and 24 feet deep was completed.	Charles River,	—	1[illegible]7 80	1 to 1 5 feet of loam, 15 feet of coarse gravel, about 45 feet of fine sand with ledge beneath.	361,213	5[illegible]0,[illegible]00	[illegible]97,857	1,302,500	1,000,000	5,000,000	
Wellesley	3,600	1884	Filter-gallery 63 feet long, 11 feet wide at bottom, and 17 feet deep. Large well, [illegible]2 feet in diameter and 20 feet deep, at William's Spring	Rosemary Brook,	—	4 28	The filter-gallery is built in a compact hard-pan. The well at Williams' Spring is in loose gravel.	257,875	33[illegible] 5[illegible]	307,8[illegible]6	463,250	—	—	The amount that could be obtained from this source in a dry year is probably less than is being used at present. Fully three-fourths of the water now comes from the well at Williams Spring.
Whitman,	4 441	1883	Filter-gallery built in two sections. First section 10 feet long, 15 feet wide, and 14 feet deep, bottom is about 12 feet below high water in the pond. Second section 410 feet long, 18 inches wide, and 20 inches high.	Hobart's Pond,	0.06*	6 40	A hard clay through which water filters very slowly. Ledge is found 20 to 25 feet beneath the surface.	103,276	175,494	206 229	451,635	Without drawing from pond 125,000	175,000	A direct connection with the pond is used in order to obtain a sufficient supply whenever the amount furnished by the well is too small.
Woburn,	13,499	1873	Filter-gallery 82 feet long and 12 feet wide, with side walls 6 feet in height, surmounted by a brick arch. The bottom of the gallery is about 8 feet below high water in the pond.	Horn Pond,	0.21	7 44	Porous gravel,	951 [illegible]89	1,127,421	1,172,850	1,308,300	1, 00,000	4,000,000	

* Very rough approximation.

‡ This area include the whole water shed of the brook opposite the wells and some territory below the wells, which probably contributes water to them.

§ This area, including territory on both sides of the river, is probably in excess of that which has contributed to the supply in the past.

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The largest supplies taken wholly from the ground are as follows:

City or Town.	Average Daily Pumping, Maximum Year.
Newton,	1,041,616 gallons.
Brookline,	964,873 "
Woburn,	951,289 "
Waltham,	687,749 "

It is noticeable that these supplies are all taken from the ground in the vicinity of large bodies or streams of water. Newton and Brookline have recently extended their works, which are now expected to yield, respectively, 2,000,000 and 1,500,000 gallons daily in a dry season. These estimates, made by engineers of long experience, are probably conservative, and may be said to represent the largest supplies of ground water yet obtained in this State. Waltham is now increasing the capacity of its source with a prospect of obtaining as much water as either Newton or Brookline. It is noticeable, however, that the ease with which these large quantities are obtained varies very much. At Waltham, it is expected to obtain the desired supply from a well 40 feet in diameter, while at Newton the works cover a total length along the river of about 4,300 feet. At each of these four places the ground water is kept pumped down below the level of the neighboring body of surface water, and there is reason to think that much of the supply is filtered surface water.

There are several supplies where a large amount of water is obtained from direct water-sheds, without being supplemented by filtration from surface water sources. As instances, the supplies of Malden, Newburyport and Revere may be mentioned.

The maximum amount pumped from these sources has been as follows:

City or Town.	Average for the Year.	Average for the Month.
	Gallons per Day	Gallons per Day
Malden,	747,446	940,403
Newburyport,	443,047	503,818
Revere,	465,491	680,411

At Malden, the amount pumped in 1890 represented a collection of 9.7 inches (or 20 per cent. of the total rainfall of 49 inches) upon a direct water-shed estimated at 1.61 square miles. At Revere, the pumping for the year ending June 30, 1891, represented a collection of 12.5 inches (25 per cent of the total rainfall of 50 inches) upon a water shed of 0.78 square miles. At all three of these places it is probable that the amount which has been pumped is more than could be pumped after one or two years of low rainfall. At Revere, particularly, experience has shown that the storage capacity of the ground is very large, so that when the water table

is reduced to a very low level during the summer, the ground will not fill before the next summer unless the amount of rainfall is above the average.

It has already been mentioned that the amount of chlorine found in the water of the filter-gallery at Woburn, shows that a large proportion of the water comes from Horn Pond. A comparison of the amount pumped from the gallery with the precipitation upon the direct water-shed leads to similar conclusions. The amount pumped during the year ending Aug. 31, 1887, was 951,589 gallons per day. The precipitation during the same period equalled 42.3 inches, which upon the direct water-shed of 0.21 square miles was equivalent to 423,000 gallons per day. The amount which can be collected is much less than the total precipitation. If we use the proportion collected at Revere (25 per cent.) as a basis, the yield from the direct water-shed at Woburn during the year mentioned would have been 105,750 gallons per day or about one-ninth of the amount actually pumped.

As instances of supplies where ground water is obtained only in small quantity, in proportion to the extent of the works, we may mention those at Lexington and Bridgewater:

At Lexington, with four large wells and a deep tubular well, the supply obtained in a dry summer is less than 100,000 gallons daily. This is owing both to the small water-shed tributary to the wells, and to the unfavorable character of the ground for storing water in the wet season of the year where it will maintain the yield of the well in the dry season.

At Bridgewater, two wells, one very large, were completed in 1888, but the next year, when the consumption of water in summer was about 75,000 gallons per day, it was found advisable to add another large well with a deep six-inch tubular well in its bottom, and in 1890 a second tubular well was sunk. The works as they now stand do not furnish any very large excess above the present consumption of about 130,000 gallons per day in summer, so that a further extension of the works is contemplated. These instances are mentioned to show that works of considerable extent do not necessarily furnish much water, unless the ground is porous, and there is either a large direct water-shed, or a neighboring stream or pond to saturate the ground.

The returns show that, in Massachusetts, wells excavated in rock do not furnish large quantities of water.

Quality of Surface Water.

As indicated in the introduction to this paper the quality of water for the supply of a city or town has to be considered from several points of view. First and most important, it must not be injurious to the health of the community. Second, it must not have a disagreeable odor or be unpalatable. Third, it should not be too hard for washing and for use in boilers.

The most important factor in making water dangerous to the health of the community is the discharge of human sewage into it, whereby the germs of specific diseases may be introduced into the water. We may, therefore, say in general terms that a water will be dangerous to health in

proportion to the density of population upon the watershed from which the supply is derived. This statement, however, needs much qualification, because it makes a very great difference whether the sewage of the population enters the water directly or is filtered through the ground from cesspools; and, even in cases where sewage does enter the water more or less directly, the time which elapses between such entrance and the drinking of the water is a very important element. For instance, the discharge of the sewage of the city of Lowell into the Merrimack River, so that within a day it may reach the intake of the Lawrence water works, is a much greater menace to the health of the inhabitants of Lawrence than the discharge of a corresponding amount of sewage from Natick into the southerly division of Lake Cochituate (where the passage to the northerly division, from which water is drawn, requires months of time) is to the health of the city of Boston. On account of this quicker transmission of the infectious matter by streams it seems fair to say, that, when polluted, they are more dangerous as sources of water supply than reservoirs and ponds.

Surface water may have a dark color owing to the drainage from swamps; or that flowing in streams may become turbid with suspended mineral matter after rains; or the water of reservoirs and ponds may be somewhat turbid and have a disagreeable taste and odor, owing to the presence of algæ and other minute organisms. It is the presence or absence of these features which can be recognized by the senses that generally determines the quality of water in the public mind. The organisms which produce the disagreeable tastes and odors are not the so-called disease germs, and the experience of cities and towns using waters which generally contain these organisms does not indicate that they have a noticeable influence upon the health of the community. When present in large numbers, however, they often make the water so disagreeable to the senses that it is unfit for drinking, and in this way are a great evil. They very rarely occur in abundance in the water of streams, but are most frequently abundant in stored waters. All stored waters, however, are not equally affected, the character of the water and the manner in which it is stored having an important influence upon the amount of these growths. Unpolluted deep ponds generally furnish a water free from bad tastes and odors, and deep storage reservoirs prepared by the removal of all of the soil and vegetable matter from the bottom and sides are equally satisfactory for the storage of water. The effect of density of population upon the water-shed is also found to be one of the most important factors in causing these troublesome growths, which seem to develop in abundance where the water is supplied with nitrogenous matter from sewage and the animal manures produced or used in populous districts. The effect appears to be nearly the same when the sewage is purified by filtration through the ground before entering the water supply, as when it is discharged directly into it.

Experience shows that where the population exceeds 300 per square mile of water-shed, the stored water, whether contained in a natural pond or artificial reservoir, is particularly liable to produce an abnormal growth

of organisms, and in consequence give trouble from bad tastes and odors. Shallow storage reservoirs from which the soil and vegetable matter have not been removed generally give trouble, and the large and deep reservoirs of the same character are by no means exempt.

The color of the water which enters the pond or reservoir does not appear to have a marked effect upon the growth of organisms. A water having much color generally has a noticeable taste caused by the vegetable matter in solution which produces the color. This taste, however, is not particularly disagreeable.

Natural waters from regions where limestone abounds are frequently too hard to be satisfactory, either for washing or boiler purposes; but, in Massachusetts, these conditions exist only in limited portions of the western part of the State. In the eastern portion of the State the natural waters are soft, and it is only through pollution that they become hard. There are, however, very few surface waters, except in the extreme western part of the State, which are not suitable for washing and for use in boilers.

There are several ways in which the purification of surface water of unsatisfactory quality can be effected by artificial methods,—as, for instance, by filtration through sand; but this can only be done with considerable difficulty and expense. It is therefore the best plan, in selecting a surface water, to obtain one which will not require artificial purification. When water is taken from the ground near streams and ponds it is often to a large extent surface water so thoroughly filtered that it cannot be distinguished from the natural ground water. This method of purification by natural filtration is an excellent one to adopt where there is a sufficient area of porous ground adjoining the surface water source.

Quality of Ground Water.

With ground waters as with surface waters, the quality must be considered from several points of view. First, the water must not be dangerous to health; second, it must be free from any bad taste, odor and appearance which will make it disagreeable as a drinking water; and third it should be suitable for domestic and boiler uses. The danger to health comes, as with surface waters, from sewage pollution; but a ground water is not as liable to such pollution as a surface water, because during the passage of the water to the well both the suspended and soluble organic matters, including the bacteria, are to a very large degree retained by the ground or oxidized into harmless inorganic compounds.

As a result of this purifying action, ground water draining from a territory which has upon it considerable population (provided it is not too near the wel) is as pure as most surface waters draining a territory much less thickly populated. This statement is not intended to encourage the location of ground water sources where they will obtain their supply from a populated district, because such action is inadvisable where an entirely uncontaminated source can be obtained, even at a large additional expense; and it is only where such a supply cannot be obtained that the relative merits of supplies from even slightly polluted territory should be considered.

It may be well in this place to call attention to the great difference which usually exists in the quality of water from public and private wells. The former are usually located at a considerable distance from any habitation, so that even if they draw polluted water from populous districts it has to pass a long distance through the ground before reaching the well, and is generally diluted by a large amount of water from other directions entirely free from pollution; and these public, wells are also as a rule, thoroughly protected from the entrance of surface washings or the accidental entrance of other foul matters. The typical private well in a village, on the other hand, often receives a considerable portion of its water from cesspools located so near it that the polluted water does not become at all thoroughly purified by its passage to the well, and the direct entrance of surface and other dirty water and foul matters is not wholly prevented.

In the foregoing statements we have had in mind sources which derive their supply from what we have before called the direct water-shed. In the case of sources which obtain their supply by natural filtration from a neighboring stream or pond, the conditions are somewhat different. Even where the color, taste and odor are so completely removed that these filtered waters cannot be distinguished from the true ground waters, the removal of the organic matter (and probably of the bacteria) is not quite as complete as in the cases of the slower and to some extent intermittent filtration from the land side. If, however, we refer to the examples furnished in Massachusetts, we find in most instances that the surface waters before filtration are contaminated so little, that after being converted into ground waters by filtration they are about as good from a health standpoint as true ground waters which more frequently derive their supply from populous districts.

There is another class of waters obtained by natural filtration from streams and ponds in such a way that the filtration is very imperfect. These imperfectly filtered waters have some of the characteristics of the surface waters from which they are derived, and some of the characteristics of the true ground waters. They also have certain special features of their own in that they contain an unusual amount of free ammonia, a product of decay, and the organism *Crenothrix*, which grows abundantly in such waters. If the surface waters before filtration are objectionable from a health stand-point, owing to the presence of disease germs, the imperfectly filtered waters are subject to the same objections (though possibly to a less degree); and the presence of the intermediate products of decomposition must also be regarded as an unfavorable feature. It is not known that the presence of *Crenothrix* affects the healthfulness of the water, but it is very objectionable for other reasons which will be pointed out subsequently.

With regard to the taste, odor and appearance of ground waters, it may be said that at all public supplies where the water is shown by chemical analysis to be completely purified by filtration, the quality of the water as it comes from the ground is satisfactory. The previous pollution of the water does not give it a disagreeable taste or odor, but, on the con-

trary, by increasing the mineral contents of the water, makes it if anything more palatable. The only trouble experienced from waters of this class occurs after they have been exposed to the light in open basins or reservoirs, when a bad taste and odor are often produced by the algæ and other organisms which find conditions favorable to their rapid growth in such waters.

The imperfectly filtered waters retain some of the taste and odor of the surface waters from which they are derived and often have a turbid appearance, owing both to the imperfections of the mechanical filtration and to the presence of the *Crenothrix* already mentioned.

For domestic and boiler uses the completely filtered ground waters are satisfactory if not too hard. In the western part of Massachusetts, where there is much limestone, the natural ground waters are frequently too hard to be satisfactory for these purposes; but in other portions of the State, except in the immediate vicinity of the sea, the unpolluted ground waters are but little harder than the surface waters, and not hard enough to be objectionable for either of the uses named. The excessive hardness of many of the village wells and of some public water supplies is due to the inorganic or mineral contents of sewage and other waste matters washed into the ground from which the supply is derived. These soluble mineral contents of polluted water cannot be removed by even the most complete filtration. It will therefore be seen that any pollution upon the water-shed of a ground water supply not only affects the quality of the water from a health stand-point, but also makes the water less satisfactory for domestic and boiler uses.

Imperfectly filtered waters are not generally objectionable on the score of hardness; but, as the organism *Crenothrix* has the peculiar property of separating the dissolved iron from water and incorporating it in its sheath where it exists as iron-rust, such waters are unsatisfactory for use in the laundry because white clothes become much discolored by the rust.

The foregoing statements are not wholly applicable to very deep wells, although, in the few instances in which wells of this character are used for public water supplies in Massachusetts, the quality of the water is about the same as that obtained from the more shallow wells. In other instances the quality of the water obtained from very deep wells has been very unsatisfactory.

It may be thought that the quality of a ground water will vary with the method adopted for its collection: as, for instance, that a driven well will furnish better water than an excavated well or filter-gallery. The examinations of the water supplies of the State do not indicate any noticeable difference in the water collected in these different ways, provided the water is not exposed to the light, and the conditions are not such as to produce imperfect filtration.

Crenothrix is the greatest pest in ground water supplies and, as has been stated, is associated with imperfect filtration. The relation of *Crenothrix* to imperfectly filtered waters has been fully discussed in a report of the Massachusetts State Board of Health upon the Examination of Water Supplies, 1890, pp. 777—782; but the subject is of so much im-

portance when selecting a ground water supply, that the conditions under which *Crenothrix* has been found in abundance will be referred to here. The principal instances are furnished by the water works at Wayland, Arlington, and Whitman. At each of these places the filter-gallery is built near the shore of a reservoir, in material which is not very porous; and at both Wayland and Arlington small branch galleries extend out under the reservoir only a few feet below its bed. In each case the chemical analyses show that the water is imperfectly filtered and contains the products of decay. It may also be mentioned that in each case the unfiltered reservoir water contains a large amount of organic matter.

There are other instances in the State where attempts have been made to obtain filtered water by means of systems of open-jointed pipes laid beneath the bottoms of reservoirs; but the quality of the water obtained has not been good, owing probably to imperfect filtration and *Crenothrix*. Still other instances in which a growth of *Crenothrix* has caused trouble are given on this and the following page.

Crenothrix has appeared in some of the ground water supplies in the State where the filtration is nearly complete, but has not multiplied to such an extent as to cause any serious trouble.

It may be asked how far it is necessary to place a well or filter-gallery from a stream to insure a practically complete filtration of water. There are several instances in the State where the bank intervening between the stream and the well or filter-gallery is not more than twenty or thirty feet in thickness, and yet the water obtained is very completely filtered. These sources, however, are located in very porous ground; and it is probable that, owing to the silting up of the bed of the stream opposite the well or filter-gallery, by far the greater part of the water has to filter by a very circuitous course. It is best, however, where practicable, to place the well or filter-gallery as much as one hundred feet from the stream, and if the material is so impervious that a sufficient quantity cannot be obtained at this distance, it may be said that the conditions are not favorable for obtaining a supply of ground water.

In addition to the ground waters, already discussed, which it has been practicable to group with reference to certain special characteristics, there are others met with under special conditions which present some peculiar features.

Wells driven in the sand in some parts of Provincetown, at the end of Cape Cod, furnish water having a very high color and a strong odor. This may be accounted for by the existence of deposits of organic matter, largely of marine origin, beneath the sand drifts of this region.

In the water supply of the Westborough Insane Hospital, taken from driven wells near Chauncy Pond, the amount of free ammonia in the water has always been extremely high, and after several years' use of the wells, has increased about a half. The organic nitrogen has also increased to more than twice the original amount, and *Crenothrix* and other organic growths are now found in the pipes, making the water unsatisfactory for use in the laundry on account of the rusty stain left upon the clothes.

Wells sunk at Lexington in peat, hard pan and rock furnish water having considerable color, and some other characteristics of surface water.

There is an instance where water taken from a filter-gallery beneath the bed of an old mill-pond has color and turbidity owing to the presence of *Crenothrix* and *Zooglœa*, is hard, and has an offensive odor. In another instance wells driven in a salt marsh have furnished very hard water. Still another instance may be mentioned in which a driven well near a large swamp has furnished a water which was colorless when drawn, but acquired considerable color on standing for a day, and also had the odor of sulphuretted hydrogen.

These special cases have not been sufficiently investigated to warrant an extended discussion at the present time, but they are mentioned to indicate the necessity, notwithstanding the general good character of ground waters, of having analyses made of water from test wells, and of considering carefully what changes in the character of the water may occur when the currents of water in the ground are changed by continuous pumping.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

Minutes of the Meeting of the Board of Managers of the Association of Engineering Societies, held in Chicago, September 11, 1891.

A meeting of the Board of Managers of the Association of Engineering Societies was held at the office of Mr. Benezette Williams, chairman, 171 LaSalle Street, Chicago, at 10 a. m., September 11th, 1891. There were present: Messrs. Fred Brooks, J. B. Johnson, Benezette Williams, L. P. Morehouse. J. A. Seddon and John Nichol. John W. Weston, Secretary of the Board, and by invitation, Mr. L. E. Cooley, President of the Western Society of Engineers. Mr. Benezette Williams briefly presented the several matters which the Board was called together to discuss—the present arrangement of publication of the Journal with Mr. Weston; the election of officers; applications for membership from other societies.

Mr. Williams called upon the Secretary to read the correspondence that had passed between the Technical Society of the Pacific Coast and the Chairman of the Board. The matter was only informally discussed as that Society had finally voted against the proposition.

The correspondence, now pending, between the Northwestern Society of Engineers and the Chairman of the Board was also presented.

The question of the publication of the Journal was next taken up. The present method of publication and its publication by the Board itself were both thoroughly discussed and considered, and the following resolution was put to vote and carried;

"That a committee of three be appointed to report on the publication of the Journal."

The Chairman appointed Messrs. Johnson, Brooks and Nichol.

The question of regularity of issue of Journal was considered,

The Secretary stated that this mainly depended upon the amount of matter on hand, and urged that the Secretaries of the several Societies use their best endeavors to prevent delay in forwarding all matter for publication.

The quality of the drawings sent for publication was discussed, and the general expression was that efforts should be made to effect a marked improvement in their quality.

A discussion then ensued on the value and quantity of matter sent to the Secretary for publication, resulting in the opinion that final control should rest with the Board.

Adjourned to 3 p. m.

AFTERNOON SESSION.

The Board again met at 3:45 p. m., and Prof. J. B. Johnson read the following report of the Committee on Publication of Journal:—

REPORT OF COMMITTEE ON PUBLICATION OF JOURNAL.

To the Board of Managers of the Journal of the Association of Engineering Societies.

GENTLEMEN:—We have examined into the matter of receipts and expenditures on account of the publication of the Journal, and find the following to be the approximate figures:

Present total annual cost of Publication, - - - -	$3,300
Present outside income (Subscriptions, advertisements and sales of back numbers), - - - - - - - -	1,000
Present net annual cost of Publication. - - - -	$2,300

There are now nearly 1200 paying members of the various Societies in the Association, and the number is increasing about 100 per annum. It seems, therefore, that we could pay our Secretary six hundred ($600) dollars a year, and without any increase of income, reduce the price of the Journal at once to $2-50 per member. We believe an efficient Secretary can be procured for this sum, provided he be given the contract for publishing the Journal, at current prices for printing, binding, etc. We also believe the income from advertisements can be very largely increased if the different Societies in the Association can be interested in obtaining them, and that the cost of the Journal can thus be reduced, or its size and character improved. We think it wise to continue the present arrangement, however. to the close of the current volume.

We suggest, therefore,

1st. That Mr. Weston be requested to continue the publication of the Journal to and including the December number, and the Special annual summary of Index Notes under the present arrangement.

2nd. That beginning with the January number, 1892, a Secretary be employed at a salary of not to exceed $600 per annum, who shall conduct all the correspondence, and other business pertaining to the office, and who shall also be employed to publish the Journal at standard current prices, keeping a strict account of all receipts and expenditures, and render an account of the same to the Chairman of this Board, on whose approval the accounts may be allowed.

3rd. That the Chairman of the Board should audit all bills and accounts, and collect from each Society quarterly, their pro rata of the estimated net cost of the publication, and at the end of each volume he should make a report to the Board, to be published in the Journal, giving a classified statement of all receipts and expenditures, which report should be subject to the inspection and approval of the Board.

4th. That each society in the Association be allowed one-half the receipts from all advertisements sent in by its Secretary to the Journal, and that such sums be placed to its credit on the Secretary's books, and deducted from its pro rata portion of the cost of publication, and that the same commission be allowed the Secretary of the Board, in addition to his salary, on all new advertisements he may procure.

Respectfully Submitted,

J. B. Johnson,
Fred Brooks, Committee.
John Nichol,

After discussion it was voted that the suggestions of the report be adopted by the Board.

The election of officers being the next on the programme. Mr. Benezette Williams was elected Chairman of the Board, and John W. Weston Secretary.

Before adjournment it was voted upon and carried "that the chairman be authorized to assess the Societies for the expenses of the Association.

Adjourned. John W. Weston, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

350th Meeting, Sept. 23, 1891.—The club met at 8 p. m. at the Washington University. President Burnet in the chair and twenty-seven members and twelve visitors present. The minutes of the 349th meeting were read and approved.

The executive committee reported the doings of its 114th and 115th meetings.

The names of John M. Nier, Henry H. Humphrey. Frederick Grant Schlosser and Henry P. Broughton were proposed for membership.

The following names were placed in nomination for vice-president: S. Bent Russell, J. A. Ockerson and J. B. Johnson.

Prof. Johnson then gave the paper of the evening, "The Government Timber Tests." The manner of conducting the tests was described in detail, and attention was called to the great value of the records obtained from such work.

Discussion followed by Messrs. Russell, Burnet, Seddon, Moore, Dean and Crosby.

After announcing the paper for the next meeting, October 7th, on the "Use of Electricity in Coal Mining," by Whitfield Farnham, the meeting adjourned to the testing laboratory. Here Prof. Johnson had arranged a full series of tests to illustrate the paper of the evening. The machine for testing large beams attracted particular attention, and the members had an opportunity of witnessing the breaking of a beam 8-in.×10-in.×11 ft.

Adjourned. ARTHUR THACHER, Secretary

351ST MEETING. OCT. 7, 1891.—The club met at 8:20 p. m. at the club rooms. President Burnet in the chair and eleven members and one visitor present. The minutes of the 350th meeting were read and approved.

Mr. Whitfield Farnham read the paper of the evening on the "Use of Electricity in Coal Mining." Mr. Farnham gave his experience in trying to introduce electrical machinery in the coal mines of the Southwest, and described the difficulties he encountered. Tables were presented giving the comparative cost of installation for plants using compressed air and electricity, and it was shown that the electrical machinery would involve a much greater first cost.

Discussion followed by Messrs. Crosby, Moore, Farnham, Melcher and Burnet.

As the executive committee had failed to get a quorum, it was moved and carried that Mr. Crosby should assist the committee in counting the votes for vice-president.

For the next meeting, October 21st, a paper by Mr. John A. Laird, on "The Temporary Low Service Pumping Plant, St. Louis Water Works," was announced.

Adjourned. ARTHUR THACHER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

SEPTEMBER 2, 1891.—The Annual Summer Meeting was held Wednesday Sept 2, 1891, the whole day being devoted to the exercises

By the kindness of President Fish, of the Illinois Central R. R. Company, a special train was put at the disposal of the Society, and at 10 a. m. pulled out from the Lake Street depot for Jackson Park, the World's Fair site, with about 150 ladies and gentlemen on board.

The train was switched from point to point of interest in Jackson Park, and the progress of the work examined. After a stay of one hour the train moved to a siding at Burnside where lunch was served on the train.

Pullman was reached at 12:45, and under the escort of Mr. Sweet, (Mr. Pullman's secretary), and other officers, a rapid inspection of the many shops of the car works were made.

At 2 p. m. the train again started, taking the Belt line, and passing over to the Madison & Northern Division of the Illinois Central, where several of the recent important bridge structures and other features of modern railroad work were examined, and the details explained by Messrs. Wallace, Robinson and Parkhurst.

The train arrived at Chicago at 5:30 p. m., and the party broke up to reassemble at 8 p. m. at the Grand Pacific Hotel.

EVENING SESSION.—The Society assembled in regular meeting at 8 p. m. in Club Room A, Grand Pacific Hotel, with some 70 members and guests present.

The following applications for membership were reported from Board of Directors:

John S. Metcalf, James McDonald, G. T. Faucon, Charles P. Kemble, Carl E

Davis, Lightner Henderson, F. Sargent, Jonathan Phillips, F. W Settan, Edward S Wills, Arthur S. Coffin, Geo. Weston.

PRESIDENT COOLEY:—It has been suggested that the evening be devoted to a general subject, rather than take up the special order which is usual on the first Wednesday of each month at the regular meeting. There are several things which have been suggested for our discussion this evening. Among them is the building question, in regard to which you have all received circulars. There is also an amendment to the By-laws in regard to the election of officers, which must come up this evening. The By-laws and Constitution of the Society do not provide any plan or system for the election of officers of the Society.

The Society is now so large that it is suggested that some definite system be made a part of the by-laws. The matter was referred to the Board of Directors at the beginning of the year, and an adaptation of the Australian system has been suggested.

A motion was made that the regular order be suspended, which was seconded and carried.

"You will notice there are two amendments to the by-laws, one practically putting into the by-laws the present custom in regard to new members. The other is in regard to the election of officers. These lie over for the second succeeding meeting under the rules; they will be printed in the minutes, and if there are any suggestions to make at this time, they will be recorded and incorporated in the minutes for the benefit of members who may wish to consider them. They will be discussed later, after every member of the society has had an opportunity to study them.

An invitation was received from Mr. Chanute to visit the Tie Preserving works at 15th and Clark streets.

At the request of the president, the secretary informed the meeting of the present state of progress of the International Engineering Congress, etc., for 1893. This had been previously published.

PRESIDENT COOLEY:—There is a report before us from the Committee on Topographical Survey, too long to read but which would come up ordinarily in the regular order of business. It should be printed and sent to members for discussion at the next meeting of the Society. If no objection is made, the president will order the document printed and distributed. It is so ordered.

Mr. Mead, of Rockford, has suggested a matter which I would be pleased to have him submit to you

MR. D. W. MEAD:—Talking with Prof. Baker to-day concerning certain matters relative to the economic geology of this state, it occurred to me to suggest to our president that possibly the society might take some action in the matter which might lead to to beneficial results. My attention has been called during the last year especially, to a comparatively new subject of only a few years' growth, that is the subject of brick clays. During the last year I had occasion to erect works for the company which I represent, and in so doing had tried to look up the question of clays in this and adjoining states and from that I drifted into the subject of Economic Geology, and what I did not find is what I would like to speak of here. I found in a number of the adjoining states, notably in Ohio and Wisconsin, a great deal of work of practical importance on these subjects. Prof. Chamberlain, in Wisconsin, has published one of the finest state geological reports which I suppose has ever been printed when time and money is taken into consideration, and in Ohio, Prof Alton has published two volumes on the economic geology of the state, which are of great value, not only to the State of Ohio, but to everybody interested. New Jersey has also done something in the same line. The New Jersey report on clay, the only original work I believe which has been attempted by any state, and almost all of which has been written since the report was published in '76—almost all has been copied from his report. I find, however, in looking up the matter of economic geology in Illinois, that we are singularly deficient in information concerning the subject. The state report of the geological survey which I have, takes up about 400 pages on the subject of paleontology, and I think about 20 pages covers all the economic questions of the state. Those in economic geology—questions which are simply copied from the mines regarding the different strata of clays in sinking the shaft, and perhaps some little information on artesian wells, that is, the

different strata and depth of each, which has been encountered in sinking artesian wells in one or two localities. It seems to me that the State of Illinois is old enough and the economic questions of this state are of enough importance to warrant at least greater attention than has as yet been given. There is at present I believe, between five and ten million dollars invested in the paving brick industry. It is a new industry, and within a few years we will no doubt have double that amount, and we have practically nothing on the clays of this state. The coal industry I am not particularly posted on, but know that it is very important and there are many other economic questions which are equally so. It simply occurred to me to-day that it might be possible that this society could take some action looking towards securing this information by legislative action, or possibly by some action through the proper officials in connection with the World's Fair. We will have the people of all adjoining states and a good many from other countries, showing their resources at the coming exhibition, and it seems to me that unless something is done, the resources of Illinois will be very poorly represented by the present printed matter, which the state presents. I am not prepared, as I say, to advance any plan or scheme or suggestions looking to this end, but simply call to the attention of the society the matter, that the question may be discussed, and if the facts in the case will waarant it, some action be taken.

Remarks were made by Mr. Guthrie and Prof. J. O. Baker upon the importance of the subject and the urgent necessity for prompt action which was supplemented by the President, and resulted in the following resolution:

That a committee of five, of which the president and secretary shall be members, be appointed to confer with the State Commissioners of the World's Fair and to do such other work in forwarding the matter as may appear proper to them.

PROF. TALBOT.—Mr. President, I have been requested on the part of the out-of-town members to offer for them their thanks to the members of the society for the many courtesies received to-day, and also to offer resolutions on behalf of the society, thanking President Fish of the Illinois Central and other officials that may have been connected with it, for the pleasure of the trip to-day, and for the many courtesies received.

PRESIDENT COOLEY:—Gentlemen, you have all heard the motion which has been offered by Prof. Talbot. The subject is not debatable. All in favor will signify by the usual sign. Carried unanimously.

Votes of thanks were also passed to Mr. Burnham, for facilities in Jackson Park, Mr. Geo. M. Pullman, and the Illinois Steel Company.

If there is no other miscellaneous business to be considered, I will call upon the secretary to read the report of the Committee on Permanent Quarters, which, however has been distributed.

The secretary then read the reports.

Speeches in favor of the building project were made by Messrs. Morehouse and Benezette Williams, and a general discussion was had touching some of the details. At the close of the remarks the following action was taken:

Resolved, That we approve the project for the organization of an auxiliary association for the construction of an engineers' building as set forth in the Prospectus and the Report of the Committee on Permanent Quarters.

PRESIDENT COOLEY:—The president has no other business before him that has been communicated or that is to be laid before the society. I will say in regard to the building question, that we have received encouragement from every quarter where it has been broached, and I have no doubt but that when our wealthiest members come back from Europe—It seems that most of them go to Europe at this time of the year—I have not very much question but that we can raise one-half of the amount among very few members of this society, so that the amount which will be called for from the general membership of the society will be relatively small. If we take courage of our desires rather than our doubts, we can carry this proposition through. It is easy to raise all sorts of conjectures, to suppose that all sorts of contingencies may arise that would defeat this object and so on, but there is one thing that I have learned, that the only way to do things is to do them, and if we set out to do these things we will do them, and if we set out not to do them, or have doubts about it, we won't do them. Now after we adjourn to the room where we are to have

our further entertainment, I trust that after you have refreshed the inner man, that you can give louder voice to your sentiments.

On motion the meeting adjourned to supper.

At 10 p. m. supper was served to which about 70 sat down. At its close the building project again received generous attention, and expectations were freely expressed as to the ultimate success of the undertaking.

JOHN W. WESTON, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. X. November, 1891. No. 11.

This Association, as a body, is not responsible for the subject matter of any Society or for statements or opinions of any of its members.

BRIDGE LEGISLATION.

REPORT OF COMMITTEE APPOINTED BY WESTERN SOCIETY OF ENGINEERS, MARCH 5th. 1890, O. CHANUTE, CHAIRMAN.

[Presented October 7, 1891.]

There is no one feature of American Engineering practice. which has been more severely criticized, both at home and abroad than the construction and maintenance of our bridges. When any serious accident occurs, more particularly those involving loss of life, newspapers comment upon the supposed recklessness and incompetency of the builders; and some of those in foreign countries where the building of bridges is wholly in the hands of engineers, are apt to characterize American bridge practice as "cheap and nasty" and to imply that our bridges are generally unsafe.

American bridge engineers know that such sweeping criticism is not deserved: that they have evolved within the last few years particular methods of designing and building bridges, by which greater strength and safety are obtained from a given amount of materials, than with the modes of construction which prevail abroad, and that bridges built by experts very seldom fail from errors in design. The trouble is that all bridges are not so built: that neither an enlightened public opinion nor such laws as prevail abroad invariably compels the employment of skilled experts to design and supervise such structures, and that bridge owners do not realize what risks they are incurring by letting contracts without professional assistance; but bridge engineers have generally forborne from insisting upon these facts, from a feeling that such course was open to the inference that their assertions might be prompted by the wish to create more employment for themselves.

It is with highway bridges that the greater risks of disaster have been incurred, and some desultory attempts have been made to promote legislation concerning them. In 1873 the American Society of Civil Engineers

appointed a committee, of which Jas. B. Eads was chairman, on the means of averting bridge accidents. This committee reported in 1875, and suggested some excellent requirements, but public opinion was relied upon to carry them out, and this proved ineffective. Since that time attention has been called to the subject by Prof. Geo. L. Vose, and Mr. J. A. L. Waddell, and by others, while the Civil Engineers Club of Kansas City, and Mr. C. F. Stowell, Engineer for the Railroad Commission of the State of New York, have separately drawn up acts to regulate the building and maintenance of highway bridges, which will be more particularly referred to hereafter, but these various praiseworthy efforts were not pushed and they all proved futile.

So little has been effected in the United States as to suggest an inquiry into what experience has led older nations to do, in order to promote the safety of bridges, and your committee determined before recommending any course to this Society, to write to various European countries to ascertain the facts. The following is a synopsis of the information so obtained:

Great Britain.

In Great Britain the safety of railway bridges is provided for by placing the matter in the hands of the Railway Department of the Board of Trade, which acts through its engineers. Each new railway is required "previously to the second notice of intention to open a railway being given" to file with the Railway Department of the Board of Trade, certain documents; those concerning bridges and viaducts being described by section 6 of the regulations as follows:

"Drawings in detail of all bridges and viaducts, either over or under the railway, accompanied by sufficient information to allow of the probable strength of each being ascertained by calculation, and by sections showing the distances between the girders, and the sides of the widest carriages to be used on the line, when the girders are more than two feet six inches above the level of the rails."

The specifications of the Board of Trade, which govern the strength of these structures, will be found in Appendix No. 1. A copy having kindly been forwarded by Mr. James Forrest, Secretary of the British Institution of Civil Engineers, to whom the thanks of this Society are due, for this and other favors.

When the drawings are received they are examined and checked over by the Engineers and Inspectors of the Board of Trade, and before permission is granted to inaugurate the traffic, the whole line of railway, including its bridges, is carefully inspected by the Board of Trade Engineers. They have powers to object either to the design or the workmanship, if they see fit, and to order defects to be made good, either at the first building, or in subsequent operation.

The Board of Trade has no jurisdiction in respect to Highway Bridges not connected with Railways. The latter are in the hands of the "County" or "Borough Surveyors," and there seems to be no legislation to promote the safety of such structures, beyond the provisions of the common law which hold the owners to an account for the accidents caused by the de-

fects in the bridges, but past casualties and a strong public opinion, demand the most ample strength and precautions, and the surveyors and engineers generally err, if at all, upon the side of safety; it being notorious that the English highway bridges are much heavier and stronger than similar structures in the United States.

France.

In France, the control of all bridge building may be said to be in the hands of the Corps of the "Ponts et Chaussees" (Bridges and Roads) or Government Engineers. The railway companies are few in number, six great companies owning much the larger part of the railway mileage of France, and all are under rigid governmental supervision and control. All plans have to be approved including those for bridges, the latter being submitted to the superior council of the "Ponts et Chaussees" through the Railway Department, and the structures being thoroughly inspected and tested by its engineers before they are allowed to be used by the public.

The Government Engineers have also the supervision of all bridges built on public roads, highways, etc., of every description. When a design is proposed either by private parties or by the authorities who belong to said corps, it is always submitted to the Engineer in Chief, and through him to the superior council or "Conseil General des Ponts et Chaussees," which acts under specifications contained in a ministerial decree of July 9th, 1877, a translation of which is herewith given in Appendix No. 2.

Work may begin in case of need before the approval of the plans, but if any correction is needed, the requirements laid down by the Council must be complied with.

For Highway Bridges the proceeding is very simple, inasmuch as they are nearly all built by the Government Engineers. Sometimes tenders with designs are called for, but the Engineer for the Department is the first to receive and examine them, and then they go through the usual series of examination by the authorities. When the structures are completed the same representation of the Government, has the testing carried out, and thereby makes certain that all the requirements are complied with.

The system is said to work well, save when very young engineers cause trouble by adhering more closely to the letter of the specifications than to their spirit. It has therefore been proposed to revise these specifications in a more liberal spirit, and this will probably be done very soon, but it is quite certain that nothing will be done to lessen in any way the security of the public by diminishing the requirements which ensure safety.

Your Committee is indebted to Mr. T. Seyrig, C. E., a bridge expert of Paris, for the information above conveyed, and also for a copy of the specifications, as contained in his work on "The Elements of Graphical Statics," a copy of which he kindly sent us.

Austria.

In Austria all Railway Bridges are subject to the control of the "Board of Inspection," which consists of Government officials under the direct

supervision of the Secretary of Commerce. Each railway is at liberty to select its own designs and to make its own plans, as, in fact, they all do; but before beginning their execution, they have to be submitted in complete detail to the board, in conformity with extensive specifications, consisting in an ordinance of the Ministry of Commerce of September 15th, 1887, a translation of which is given in Appendix No. 3.

After careful investigation and approval of these plans, the "Board of Inspection" gives its permission in writing to proceed with the work, and supervises its proper execution in every stage of its advancement. Upon its completion, the structure is inspected and tested by a delegate of the board, before traffic is permitted to begin. The permission for this, if all is right, being also in writing.

After the bridge is in use the owners are required to watch it permanently, and to apply for a Government inspection in the course of every six years. If however at any time the bridge is thought to be in a dangerous condition, an inspection by a government delegate is called for at once, and the Board of Inspection has also the right of investigating and testing the bridge at any time. Moreover the railway companies are prohibited from loading any bridge with a greater load than that originally intended. Such highway bridges as span railway tracks or approaches to the railways, are also under the supervision of the Austrian Board of Inspection, upon the same conditions.

Highway bridges, if intended for a large city, are designed by the building department of the same, but the plans must be submitted for approval to the technical department attached to the Governor of the province in which the city is located.

Each province is divided into districts, similar to our counties, and each such district has its own Engineering Department, supervising all technical matters. At the head of such a department is, as we would call him here, a County Engineer.

If the Highway bridge is to be built in such a county, the designs are made in the Engineering Department, or if not made there, have to be submitted to it for approval. Supervision is exercised at all stages of the construction, and before a bridge is allowed to be used a commission makes a thorough inspection and test. In this commission there is a delegate from the County Engineer, who has to issue a certificate of approval in writing if everything is found all right, or to condemn the structure if not in full accordance with the plans previously approved. The cost of inspection to be borne by the owners of the bridge.

Every six years the bridges undergo a careful inspection, and to prevent loading with a greater weight than that originally intended, a sign is affixed at each end, stating the largest load admissible. The specifications are covered by the ordinance of September 15th, 1887, (Appendix 3) for a copy of which the society is indebted to Mr. E. Pontzen formerly of Vienna, and now of Paris, France.

Germany.

Your committee regrets that through a series of mischances the infor-

mation which it has sought, through two different channels, concerning the laws and practice which regulate the building and maintenance of bridges in the various states ot Germany,* has not yet come to hand. It is understood however that they are fully as rigid as the practice in Austria. and that nobody is permitted to erect a public bridge without the most ample government control and test. The Government Engineers have their own way, and the public is not permitted to take risks even if it wants to do so, and thus bridge failures and accidents are said to be very rare in Germany.

Similar bridge practice is understood to prevail in other European countries, and in fact in all the older enlightened communities, past experience has led to government regulation and inspection of structures used by the public, and the organizations to effect this purpose are such as to place the matter in the hands of trained experts.

It thus appears that in the various countries named, legislation concerning the safety of bridges has naturally divided itself into two classes One concerning railway bridges, which has been put into the hands of special commissions assisted by engineers, and the other concerning highway bridges, which has been put under the control of the engineers attached to the government authorities.

The logic of necessity is producing like results in the United States. At first there was no legislation, and the people were free to erect just such bridges as they chose. The more prosperous and important railroads, moved by the sense of their pecuniary responsibility at common law, employed skilfull engineers, and in many cases established special bridge departments; but some of the new railroads, built on speculation or for sale, sometimes took considerable risks to avoid spending money. Then legislation followed to control this among other things, so that now there are Railroad Commissions in most of the states, which have taken up, incidentally as it were, the question of safety of railroad bridges.

First among these states was that of Massachusetts, which established a Board of Railroad Commissioners in 1869. From that time until 1883 one of the members of the Board was a civil engineer. Since 1883 there has been no civil engineer on the Board. In 1887 the Buzzey bridge disaster happened, and it was in consequence of the investigations made by the Board, and a report thereon, that an act was passed in 1887, relating to the examination of railroad bridges, which is herewith given in Appendix No. 4.

In accordance with the provisions of that act, the board selected Prof. Geo. F. Swain, of the Massachusetts Institute of Technology, as its bridge engineer, and he continues to act in that capacity, examining plans, strain sheets, and reports of the condition of the bridges, furnished by the railroad companies, inspecting the structures in the field upon occasion, and making both special and general yearly reports to the board, which considers his work as of essential importance. As a result of this, of the

*Prussia, Bavaria, Baden, Wurtemburg and Saxony have separate but similar laws and regulations.

1,658 railroad bridges in Massachusetts, 354 have been built new, from July 1887 to December 31, 1890, and 531 have been either renewed or considerably strengthened within the same period, so that the engineer is enabled to report that "speaking generally, the bridges in this state, are in excellent condition." In a previous report he had said "that it must not be supposed that the bridges, which have been renewed or strengthened were in all cases in a dangerous condition. On the contrary many were renewed which would perhaps have been safe for some years, but which nevertheless did not afford the proper assurance of safety under all conditions."

Mr. Geo. C. Crocker, chairman of the board, to whom the thanks of this society are due for all the above information concerning Massachusetss, adds in his letter to your committee:

"We are well satisfied in this state, that it is wise that there should be a thorough supervision of bridges by competent state authority. I think it important to call your attention to the fact that we require not only the strain sheets of the various railroad bridges, but plans showing all details, and that very careful examination of all details of every bridge is made. The principal faults which have been detected, are not excessive strains in the main parts, but faulty connections and other details. Probably the greater part of the work of strengthening, which has been carried out since 1887 has been in correcting errors in detail. I am of the opinion that this feature should be emphasized in your report."

The State of New York established a board of railroad commissioners in 1883, and within a year thereafter the board issued a circular requesting from the railroads, drawings and strain sheets of all the truss bridges upon their lines. These when received were critically examined by Mr. C. F. Stowell, the bridge engineer of the board, with the result that out of some 2,500 railroad bridges in the state, 669 have been criticized by the board,of which 535 have been repaired and 134 entirely rebuilt. The commissioners issued June 30, 1891, an illustrated volume of 1,877 pages in which it gives the result of its labors, together with the diagrams and tables of strains of every member of every railroad truss bridge in the state, and it is evidently greatly increasing the safety of the traveling public.

Your committee has not ascertained accurately what the other state commissions are doing toward promoting the safety of railroad bridges, but understands in a general way that they are giving the subject attention. In Illinois, for instance, an engineer is attached to the commission, and inspects bridges in the field when requested to do so, the board then taking any action needed. It is quite certain that the checking of strains, examination of plans, and inspection of railroad bridges will eventually come to pass through the railroad commissions in all the states, and your committee considers that, so far as the railroads are concerned, the question of bridge safety is in process of solution. The commissioners have generally sufficient powers, and are sure in time not only to regulate the construction of new bridges, but to cause the inspection,measurement and calculation of existing bridges, in order to make certain that they shall be as safe as it is possible to make them. The organizations for that purpose

are already provided, and your committee does not deem it wise to recommend at this time any additional legislation.

It may, however, call attention to the fact that the most prolific cause of accidents on railroad bridges seems to be the disarrangement of the floors under derailed trains, and that something seems to be required of engineers to ascertain, and to make known, the best and safest practice. Your committee has gathered quite a number of plans of railroad bridge floors, as now in use on various lines, and Mr. J. F. Wallace, one of the committee, will probably present a paper on this subject at a future meeting of this society.

With respect to highway bridges the case seems to be quite different, and outside of the common law, your committee knows of no legislation to protect the public against disaster. In the large cities there are generally engineering departments which possess skill,and which erect efficient structures, but in the country districts there are no organizations with sufficient technical knowledge to stand between the buyers and sellers of bridges.

The consequences is that in the rural regions, highway bridges are constantly breaking down. The failure, under a crowd, of the one at Dixon, in this state, in which sixty persons were killed will be remembered, and Professor George L. Vose, writing in 1880, estimated that not less than two hundred highway bridges had broken down during the preceding ten years. The number of failures per decade, must be greater than this now, to judge by the newspaper accounts, but many of these failures occur under such ridiculously small loads, that there has been no great catastrophe to shock the public into taking action. There is no question, however, and it must be within the knowledge of many members of this society, that many highway bridges are so weak, and with such faulty connections as to invite disaster, and that they only await an unusual load, or a combination of unfavorable conditions to cause their collapse. It is hoped that in the discussion of this report, members who are in possession of data upon this point will give in their experience, to serve as a basis for convincing those who have not given attention to the subject.

The primary cause of this condition of affairs is, that county authorities, who under the present system have entire charge of the purchase and maintenance of highway bridges, are, except in unusual cases, ignorant of any matters relating to bridge construction, and are incompetent to suitably let the contract. They naturally desire to save money for their constituents, and generally let the bridge to the bidder who will make the lowest price and guarantee the largest working load, without consulting experts to know whether the price is really a fair one, or whether there is a proper margin of safety under the working load.

Moreover, county authorities are frequently gullible, and believe the bridge seller when he tells them that the employment of an engineer is a useless expense, so that county bridges are constantly being built without proper engineering supervision, which are much too weak for their intended use, and only await a crowd of people, a stampeded drove of cattle or a heavy road roller to break down.

The communities not only get an unsafe structure, but they are fleeced into the bargain. The bridge sellers frequently form pools to simulate competition, while really paying commissions to the unsuccessful bidders, and a price is exacted for the structure which is not only too high, but actually more than a proper and safe bridge would cost. All this is notorious and has long been understood by engineers who make a specialty of designing and building highway bridges. Your committee could fill many pages with the almost incredible stories which are told of the ways in which county authorities are imposed upon, but the curious in this matter are referred to the pamphlets of Professor George L. Vose on "Bridge Disasters in America," to that of Mr. J. A. L. Waddell, entitled "General Specifications for Highway Bridges," and to an article by Mr. C. F. Stowell on "A Proposed System of Highway Bridge Supervision for the State of New York," published in the Engineering News, March 22nd and 29th, 1890.

To this unsafe condition of affairs there is but one remedy. It is to follow the foreign example: to place the building and maintenance of highway bridges in the hands of expert bridge engineers, and to hold them responsible for the results. In other words, in order to secure safe bridges for the public, the owners of such structures must be compelled by law to intrust their construction and supervision to competent persons. This is what has been done in European countries, and this is what will have to be done in the United States.

There are several ways in which organizations can be effected for this purpose. In France, as we have seen, the state maintains and pays a special body of engineers for that duty. In England the matter is in the hands of the County or Borough engineers, sustained by a strong public opinion. In Austria and Germany it is in charge of the District engineers, under the control of the governing authorities. In this country two methods have recently been proposed. One in 1888 by the Civil engineer's Club of Kansas City, which, through a committee, promoted the introduction of an act in the legislature in Missouri, which failed to become a law, and which is given herewith in Appendix 5, and the other in 1890, by Mr. C. F. Stowell, engineer for the Railroad Commissioners of the state of New York, who drew up and published the draft for an act, which was never introduced into the legislature, but which is given herewith in Appendix 6.

The latter act provides that the building and maintenance of the superstructure of all highway, roads and street bridges, 14 feet or more clear span (with some specified exceptions), in the state of New York, shall be under the general charge of an engineer styled as "Superintendent of Bridges," appointed by the governor, and of such assistants as the Superintendent may select. To this plan which has been proposed before, it has been objected: first, that this purely technical matter might become tainted with politics, and second, that it might involve the state in large expenditures.

The Engineers Club of Kansas City endeavored to obviate these objections by putting the whole expense upon the owners of the bridges

through fees paid to the "Bridge Experts," who were in turn required to make certain payments into a "bridge fund," to defray the expenses of such investigations as could not properly be charged to the bridge owners. These "bridge experts" would in a short time practically have become self recruiting, and probably keep out of politics, but the weak point in the plan probably was that it would impose upon the governor, who is to have the appointing of the experts, and the ordering of investigations, more than he could well attend to.

Your committee believes that it would be preferable to provide a special engineer to look after the safety of bridges, and that he should be paid by the state It does not deem the objections heretofore mentioned to this plan to be insuperable, and thinks that an act properly drawn can keep him out of politics, and keep the expense to the state within $8,000 or $10,000 a year. The objects to be accomplished are few and simple, and may be stated as follows:

First. To ensure the safety of new bridges by providing that they shall be designed and erected under the supervision of skilled experts.

Second. To compel the examination of existing bridges, and to make such improvements as may be required, these probably consisting of remedying faulty connections and other details, as emphasized by Mr. Crocker.

Third. To instruct the county authorities as to the most economical and efficient ways of caring for their bridges, and renewing them when required.

This should be accomplished with as little personal machinery and expense as possible, and it seems not unlikely that a beginning might be made in this state through the existing Railroad Commission, should conference and deliberation indicate this to be practicable.

Your committee does not deem it judicious at this time, to report the draft of an act. It prefers to invite first a discussion of what legislation it is practicable to bring about, by the members of this society, and whatever public spirited citizens can be interested in the subject.

For this purpose it is suggested that this report be printed and distributed, and that it be made the subject of discussion at some future meeting, to which shall be invited members of other engineering societies, the members of the Railroad Commission, counsel skilled in law making, and other prominent citizens, in order to have the benefits of their advice in a matter which seems to be of public importance.

At this meeting it is proposed by Mr. W. E. Williams, one of this committee, to submit the draft of an act, which he has prepared to serve as a basis for discusssions and improvement, and it is hoped that the result will be the evolution of some projected law to be submitted at the next term of the legislature.

COMMITTEE: *O. Chanute*, *W. E. Williams*, *Maurice Seifert*, *Edward C. Carter*, *J. F. Wallace*.

APPENDIX 1.

English Bridge Regulations.

Specifications of Bridge Requirements, Railway Department, Board of Trade.

Previous to the second notice of the intention to open a railway being given, drawings in detail of all bridges and viaducts, either over or under the railway, accompanied by sufficient information to allow of the probable strength of each being ascertained by calculation; and by sections showing the distances between the girders and the sides of the widest carriages to be used on the line, when the girders are more than two ft. six in.above the level of the rails, must be sent to the Railway Department, of the Board of Trade.

Cast iron must not be used for railway under-bridges, except in the form of arched ribbed girders, where the material is in compression.

In a cast-iron arched bridge, or in the cast-iron girders of an over-bridge, the breaking weight of the girders should not be less than three times the permanent load due to the weight of the superstructure, added to six times the greatest moving load that can be brought upon it.

In a wrought iron or steel bridge the greatest load which can be brought upon it, added to the weight of the superstructure, should not produce a greater strain on any part of the material than five tons, where wrought iron is used, or six tons and a half, where steel is employed, per square inch.

The engineer responsible for any steel structure should forward to the Board of Trade a certificate to the effect that the steel employed is either cast steel, or steel made by some process of fusion subsequently rolled or hammered,and of a quality possessing considerable toughness and ductility, together with a statement of all the tests to which it has been subjected.

The heaviest engines, boiler trucks, or travelling cranes in use on railways afford a measure of the the greatest moving loads to which a bridge can be subjected. These rules apply equally to the main and the transverse girders.

It is desirable that viaducts should, as far as possible, be wholly constructed of brick or stone; and in all such cases they should have parapet walls on each side, not under 4 feet 6 inches in height above the level of the rails, and not less than 18 inches thick.

Where it is not practicable to construct the viaducts of brick or stone, and iron or steel girders are made use of, it is considered best that in important viaducts the permanent way should be laid between the main girders. If, however, in such viaducts the main girders are placed below the level of the rails, substantial parapets not under 4 feet 6 inches in height must be provided. In important viaducts, substantial guards should be fixed outside, above the level and as close to the rails as possible, but not so as to interfere with the steps or any of the working parts of the engine or trains.

Where iron is made use of for the construction of the abutments or piers which are intended to support or carry the iron girders of high bridges and viaducts, it must be distinctly understood that these abutments or piers should not consist of cast-iron columns of small size, such as 12, 15, or 18 inches in diameter.

In all large structures of this kind the stability of the work must be such as will provide for a wind pressure of 56 lbs. on the square foot.

All castings for use in railway structures should, where practicable, be cast in a similar position to that which they are intended to occupy when fixed.

The upper surfaces of the wooden platforms of bridges and viaducts should be protected from fire. — *December 1885.*

APPENDIX 2.

French Bridge Regulations.

French Ministerial Circular, Regarding the Tests to which Metallic Bridges must be Subjected

Versailles, July 9, 1877.

M. Le Prefet: An official circular of February 26, 1858, has already regulated the tests to which metallic railway bridges are to be subjected. Another circular of June 15, 1869, has determined the tests to be made upon metallic railway bridges. Various suggestions have been submitted to the Administration concerning the tests upon these structures, and one of my predecessors after consultation with the Conseil General of Roads and Bridges, has directed a special commission composed of Inspectors General, and of Engineers of Roads and Bridges, to examine proposed modifications and to report upon the changes, which it may be desirable to make in the regulations prescribed in the circulars mentioned.

Upon the report of this Commission the Conseil General of Roads and Bridges has concluded, and I concur therewith, that metallic bridges should comply with the following conditions:

Regulations For Railway Bridges.

1st.—Metallic bridges which support railway tracks, must at all times be in a suitable condition to carry safely all locomotives, and trains authorized to run over the system to which the bridges belong.

2nd.—The proportions and sizes of the members of the trusses must be such, that when the load is in the most unfavorable position for the structure, that the strain on the metal per square inch will not be greater than is indicated below:

2,133 lbs. for cast iron in direct tension.
4,267 " " " " tension in beams.
7,112 " " " " compression, either directly or in a beam.
8,534 " for forgings or rolled iron, either in compression or tension.

The Administration may at any time admit higher strains in the case

of large bridges, when sufficient reasons, relating either to the material, the sizes or the arrangement or the parts, are given.

3rd.—The designers of metallic bridges must show by calculations in sufficient detail, that they have conformed to the requirements of the preceding article. Calculations relating to the trusses may be based on the assumption of a uniformly distributed load. In such cases they will be based upon the following table of live weights per running foot for each track:

Length of Span. Feet.	U'f'ly D'st'b'd Load lbs.	Length of Span. Feet.	U'f'ly D'st'b'd Load. lbs.	Length of Span. Feet.	U'f'ly D'st'b' Load. lbs.	Length of Span. Feet.	U'f'ly D'st'b'd Load. lbs.
6.56	26,460	36.09	15,210	65.62	10,804	229.66	7,717
9.84	23,150	39.37	14,330	82.02	9,922	262.47	7,497
13.12	22,490	42.66	13,670	98.43	9,482	295.28	7,277
16.40	21,600	45.93	13,000	114.83	9,261	328.09	7,056
19.68	20,940	49.21	12,560	131.24	9,040	410.11	6,835
22.97	19,620	52.49	12,120	147.64	8,820	492.13	6,615
26.25	18,300	55.77	11,900	164.04	8,599		
29.53	17,190	59.06	11,460	180.45	8,379		
32.81	16,090	62.34	11,250	196.85	8,158		

Note.—The loads corresponding to intermediate spans are to be determined by interpolation. The dimensions of parts which are not portions of the trusses, and notably floor beams, must be calculated for the greatest strain which can come upon them.

4th.—Each metallic span must be subjected to two kinds of tests, one by dead and the other by moving load. These tests are to be made by special train composed of locomotive engines and freight cars.

For non-continuous trusses the length of the testing train between the extreme axles, must be at least equal to the length of the longest span to be tested. For continuous trusses the testing train must be of such length as to cover the two longest consecutive spans. The total weight of the testing train must at least equal a train of equal length, composed of a locomotive weighing with its tender, 79.4 net tons, and of cars following, each weighing 16.5 net tons.

The test for the dead load will be conducted in the following manner:

For non-continuous trusses the testing train will be placed successively so as to cover it entirely. It will remain in each of these positions for at least two hours after deflection of the span has ceased.

For bridges with connected spans, each span shall be first loaded separately as above tested. For this purpose the trial train shall be divided so that the length of the forward portions shall not be materially greater than that of the longest span. Then the two spans contiguous to each pier shall be loaded simultaneously, to the exclusion of all the others, by placing thereon, the whole of the trial train.

For spans where the floors are sustained by metallic arches, the load will first be distributed upon the whole span, and then upon each half alone.

The rolling load tests will be of two kinds.

The first will be made by running the testing train over the bridge at a speed of not less than 15.53 miles per hour.

The second will be made by means of a train of the heaviest passenger coaches in use, and of a length at least equal to that of the longest span to be tested. This train shall pass over the bridge at speeds varying from 21.75 to 31.07 miles per hour. However, the high speed test may be postponed until such a time that the track at the end of the bridge shall be thoroughly settled.

The regulations which have just been laid down apply to single tracked bridges, as well as to bridges of two independent tracks, which shall be separately tested.

For bridges where two tracks are carried by the same trusses, the dead load test will first take place on each track separately, the other being empty. Then upon the two tracks simultaneously. The same method will be used for testing the rolling loads, and the simultaneous test of the two tracks will be made in this case by means of two trains moving in the same direction at the velocity fixed above.

The tests will be carried on in each case by the Engineers in Chief of the Construction and Operation of Railways, acting in concert with the company's representative.

5th.—The current use over such bridges of locomotives weighing with their tenders more than 79.4 tons, shall not be permitted without special authority from the Minister of Public Works.

6th.—When the weight of the rolling stock, which is intended to operate over the bridges, shall be notably less than that of the test strain defined in article 4, the General Administration shall decide in how much the regulations in this article, and in article three may be modified.

The Administration moreover reserves the right of considering exceptional cases, which may require alterations in these regulations.

Regulations For Highway Bridges.

1st.—Metallic highway bridges must be in proper condition to allow safe passage to all vehicles, the use of which is permitted under the highway police regulations of the 10th of August, 1852; that is to say, two wheeled vehicles drawn by not more than five horses, and four wheeled vehicles drawn by not more than eight horses.

2nd.—The dimensions of the metal portions of the spans shall be so calculated, that when the maximum load is in the most unfavorable position, and notably under the strains due to the test described in article 3, the maximum strain of the metal per square inch shall not be greater than the following:

2,133 lbs. for cast iron in direct tension.

4,267 lbs. for cast iron in tension in beams.

7,112 lbs. for cast iron either in direct compression, or in compression in beams.

8,534 lbs. for forgings or plates, either in tension or compression.

The Administration may at any time admit higher strains in the case of large bridges, when sufficient reasons relating either to the materials, the sizes or the arrangement of the parts are given.

3rd.—In the calculation for the strength of the trusses it will be assumed that the weight of the heavier vehicles and loads combined will be 12.13 net tons for two wheeled vehicles, and 17.65 net tons for four wheeled vehicles. The distance between the axles in the last case being assumed at 9 feet 10⅛ inches.

In localities where these requirements would be too severe, they may be modified according to local circumstances, but in no case shall the weight of the vehicle with its load be assumed to be less than 6·62 net tons for two wheeled vehicles, and 8.83 net tons for four wheeled vehicles, for any road subject to highway police regulations.

In those calculations which relate to the trusses, that combination shall be assumed for the roadway which shall produce the greatest strains, either a load of 61.45 lbs. per square foot, uniformly distributed, or else a load composed of as many vehicles, of the weight previously stated, which the floor of the bridge can contain with their draft animals, upon as many roadways as provided for by the bridge. As between vehicles of two or four wheels, those shall be chosen which shall bring the greatest strain upon the members of the bridge. It will be assumed that a row of vehicles will occupy a space of 8 feet 2⅜ inches in width. In any case the foot walks will be considered as carrying a load of 61.44 lbs. per square foot.

The dimensions of all parts, which are not portions of the trusses, and notably the floor beams, must be calculated for the greatest strain which can come upon them.

4th.—Each metallic span will be subjected to two kinds of test, one by dead, the other by moving load.

The first will be made by means of a load of 61.44 lbs. per square foot uniformly distributed over the floor of the bridge. This load shall remain in place for at least two hours after all deflections have ceased in the floor including the footways.

If the bridge is composed of continuous girders, each will be loaded separately, then those adjacent to each pier will be loaded, the others remaining light. Spans composed of metallic arches will be first loaded upon the whole of the span, and then upon each adjoining half.

The test of the rolling load will be made with either two or four-wheeled vehicles, selecting those, which upon being loaded, as stated in article 3. will create the greatest possible strain. This will be done by driving on a walk across the floor of the span as many vehicles as it may contain with their draft animals, in as many rows as the roadways of the bridge will permit. In the case of continuous trusses, the length of each row of vehicles shall cover the total length of the two longest consecutive spans.

The test for the dead load as above directed, need not be applied to spans of less than 39 feet 4⅜ inches, but for such spans it will only be necessary to place upon the floor, for at least two hours, and in such manner

as to completely cover it, the rows of vehicles indicated for the rolling test.

5th.—The passage of loads over the bridge, greater than those above stated for the calculations of the strength of the structure, shall not occur except by special authority of the Prefet, made upon the report of the Chief Engineer of the Department.

The Administation reserves the right in exceptional cases of considering reasons which may modify the foregoing requirements.

APPENDIX 3.

AUSTRIAN BRIDGE REGULATIONS.

1—New Railroad Bridges.

SECTION 1.—All proposals for new railway bridges must be submitted to the Ministry of Commerce for approval, before construction is commenced. The following information and plans are to be furnished:

(*a*)—A general map on a scale of one in one-thousand showing the location of the bridges, and a plan of the piers and abutments, with detailed drawings of the same on a scale of one in one-hundred, stress diagrams and general and detail drawings of the main girders or trusses (the latter to be on a scale of one in ten, one in fifteen, or one in twenty if general working drawings are added) with statements of the sizes and shapes and kinds of material used in the construction of their members.

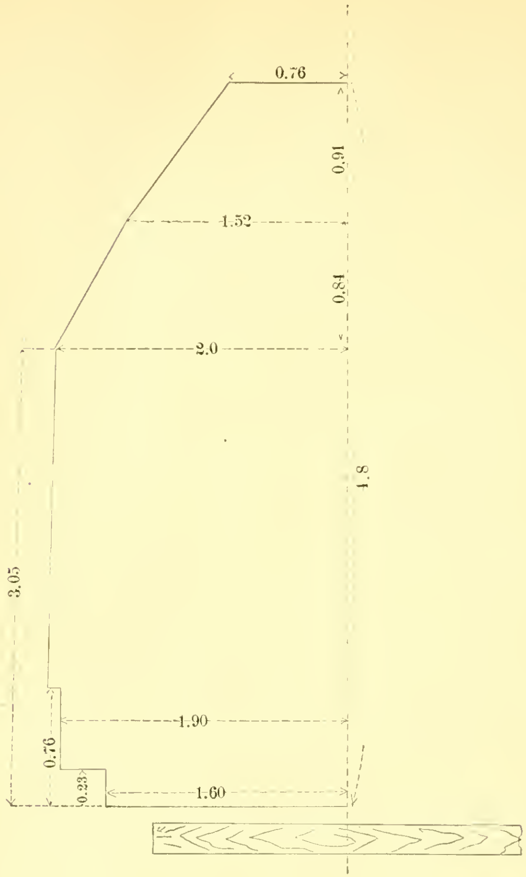
(*b*)—A statement of the dead weight of the structure.

(*c*)—Theoretical calculations of the dimensions adopted for the component parts, and in the cases of local or traction railways, a strain diagram must be prepared with the heaviest rolling stock in use as a basis.

(*d*)—For bridges of over 65 ft. 7½ in. (20 metres) length of span, or for those of unusual systems or proportions, a calculation must be furnished showing the greatest deflections of these structures (greatest elastic changes of form) under the live load.

SEC. 2.—The floor of deck bridges is to be of such width that there shall be at least 7 ft. ⅝ in. (2.15 metres) in the clear between the center of the track and the nearest hand rail posts or the edge of the planking. In the case of through bridges, the same clear distance as a minimum is to be provided between the track centers and any of the chord or diagonal members, up to a height of 6 ft. 6¾ in. (2 metres) above the planking. At posts and brackets a somewhat reduced clearance is admissible. For these and all such parts as have not been especially named, the profile, next page, indicates the minimum clearance to be provided for. The dimensions given are in metres.

SEC. 3.—The computations are to be based upon the constant (dead) and the occasional (live) load produced by the rolling stock. Besides these effects the influence of the wind pressure must be duly considered, and also that of the changes of temperature, if the construction calls for it. Calculations must be made to conform to the following requirements:



(*a*) The calculation of the chords of discontinuous girders is to be based on the assumption of a load according to the scale given below. The load is for each track and for each 3 ft. 3⅜ in. (1 metre) of span, and is uniformly distributed. The length of the span being considered as the distance from center to center of abutments. The lengths of span are given in metres, and the loads are in metric tons.:

SCALE A.

Length of Span.	Load per Metre.	Length of Span.	Load per Metre.	Length of Span.	Load per Metre.	Length of Span.	Load per Metre.
1.0	30.0	2.5	13.5	15.	7.0	80.	4.4
1.5	20.0	5.0	11.5	20.0	6.5	120.	3.8
2.0	15.0	10.	8.5	40	5.6	160.	3.4

For intermediate lengths of span, interpolate in arithmetical proportion.

(*b*)—The maximum shearing strain in the web of such structures must be determined for each section of the span, by loading that portion of the span only, which intervenes between the section under consideration and the abutment. For this portion of the calculations the following scale of loads is given. It applies regardless of the total length of span, the loaded portion alone being considered.

SCALE B.

Length of loaded section. Metres.	Load per metre of length. Tonnes.	Length of loaded section. Metres.	Load per metre of length. Tonnes.	Length of loaded section. Metres.	Load per metre of length. Tonnes.
1.0	30.	5.0	14.0	40.	6.2
1.5	25.	10.0	10.0	80.	4.8
2.0	20.	15.0	8.5	120.	4.0
2.5	18.	20.0	7.0	160.	3.5

For intermediate lengths of span interpolate in arithmetical proportion.

(*c*)—In the case of continuous girders, the calculation of the chords must be based upon the full loads of the span lengths, applied by the use of scale A, and those combinations must be considered which produce the largest moments. In the calculation of the web members of a given span, the loads within this span affecting those members are to be taken from scale B, while the loads of adjoining spans affecting these members are to be taken from scale A.

(*d*)—Where the loads from scales A and B are not directly applicable, as in the case of arches, cantilevers, etc., the following moving loads producing the same effect on an ordinary truss or girder are to be assumed:

1.—Three eight-wheeled locomotives, their extreme length being 31 ft. 2 in. (9.5 metres), their wheel bases 11 ft. 9½ in. (3.6 metres) center to center of exterior axles, and their axle load 15.43 net tons (14 metric tons).

2.—Three six-wheeled trailing tenders of 20 ft. ⅛ in. (6.1 metres) extreme length, and of 9 ft. 10⅛ in. (3 metres) wheel base, and 11.02 net tons (10 metric tons) axle load.

3.—A train of four-wheeled trucks to follow, their lengths out to out to be 22 ft. 11½ in. (7 metres), their wheel base to be 9 ft. 10⅛ in. (3 metres), and of 8.82 net tons (8 metric tons) axle load. In the case of short spans the axle loads are to be taken at 15.43 net tons (14 metric tons) to provide for unusual loads on single axles, while in the case of long spans all axles cannot be considered as abnormally loaded.

(*e*)—In the calculation of floor beams the load to be used is one-half that resulting from the use of scale A, for a span whose length is equal to the distance between the nearest floorbeams on each side of the one under consideration. End floorbeams must be calculated according to the structural features in each case, the missing neighboring floorbeam in the sense

of the preceding paragraph, must be substituted by an ideal one at the proper distance. Road stringers are to be treated in the same manner as main girders supported by floor beams.

(*f*)—The effect of wind pressure is to be determined by the supposition that there is a side pressure equal to 55.331 lbs per sq. ft. (270 kilos per sq. metre) on the surface of the unloaded bridge, and of 34.8 lbs. per sq.ft. (170 kilos per sq. metre) on the surface of the loaded bridge. The least favorable result is to be made the basis of calculation. The effective wind surface is to be determined as follows:

1.—In the case of the unloaded bridge the surface of the exposed truss is to be measured full. The surface of the truss on the opposite side may be reduced according to the scale below.

Ratio of Open Portion of Truss to the Entire Outline.	Proportional Reduction of Area of Exposed Surface of Leeward Truss.
0.40	0.2
0.60	0.4
0.80	1.0

(*g*)—In the case of certain systems of construction which are subject to increased strains in consequence of changes of temperature, such as arch bridges, continuous girders over high iron bents, etc., such additional strains must of course be considered. Besides these, dynamic effects, which may result from certain conditions of the track, or from the train speeds to be employed, must be taken into account. Ten per cent of the live load effects must be added for impact.

(*h*)—In cases of local or traction railways of standard gauge, over which heavy eight-wheeled locomotives never pass, the loads scheduled under scale A and B may be reduced as follows:

1.— When the heaviest locomotives do not exceed 25 ft. 3⅛ in. (7.7 metres) in length out to out, the number of axles being three, spaced 3 ft. 11⅜ in. (1.2 metres), axle load not over 13.23 net tons (12 metric tons), trailing tender 20 ft. 8 in. (6.3 metres) out to out, on three axles, the aggregate load on which does not exceed 27.55 net tons (25 metric tons): the admissible reduction is twenty per cent.

2.—In the case of such bridges as are never used for any heavier loads than three-axled tender locomotives of 23 ft. 7½ in. (7.2 metres) total length, 3 ft. 7⅜ in (1.1 metre) between the axles, and 9.37 net tons (8.5 metric tons) axle load; the admissible reduction is forty per cent.

Sec. 4.—The material under the loads specified in section three, subheads *a*, *b*, *c*, *d*, *e*, *g*, and *h* shall not be strained beyond the limits herewith stipulated, due deductions being made for rivet holes and other ineffective area of section. The unit of section to which the loads apply being one sq. in.

(*a*)—For wrought iron in tension, compression or shear:

1.—Under 131 ft. 2⅞ in. (40 metres) span, 9,956 lbs. per square inch; (700 kilos per sq. centimetre) plus 28.45 lbs. per square inch; (2 kilos per sq. centimetre) for each 3 ft. 3⅜ in. (1 metre) of length.

2.—Above 131 ft. 2¾ in. (40 metres) in length as follows:

(40 metres)	131 ft. 2¾ in.	11,094 lbs. per sq. in.	(780 kilos per sq. cm.)
(80 metres)	262 ft. 5⅝ in.	11,947 " " "	(840 " "
(120 metres)	393 ft. 8½ in.	12,516 " " "	(880 " "
(160 metres)	524ft. 11¼ in.	12,801 " " "	(900 " "

For intermediate lengths of span interpolate in arithmetical proportion.

The distance between the points of support of floor beams and stringers is to be considered as the length of their span.

3.—Rivets in shear. If in one direction only 8,534 lbs. per sq. in. (600 kilos per sq. cm.), if in shear in more than one direction 7,111 lbs. per sq. in. (500 kilos per sq. cm.). Pressure on bearings in plates, never to exceed 19,912 lbs. per sq. in. (1,400 kilos per sq. cm.).

4.—Shear in the direction of the fibres 7,111 lbs. per sq. in (500 kilos per sq. cm.).

5.—Wrought iron of 51,203 lbs. per sq. in. (3,600 kilos per sq. cm.) ultimate resistance must elongate in the direction of the fibre at least twelve per cent. With the least admissible ultimate resistance equal to 46,936 lbs. per sq. in. (3,300 kilos per sq. cm.) the elongation must not be less than twenty per cent. The elongation is to be measured in lengths of 7⅞ in. (20 centimetres), with a test bar of 0.77 sq. in. section (5 sq. cm.). If it is impossible to obtain a test bar of the prescribed area, the elongation will be measured in a length, the square of which bears the same relation to the area of the cross-section of the test piece as $20^2 : 5$.

(*b*)—For cast iron, which should not be used in important parts of any framed structure, the limits are fixed at 9,956 lbs. per sq. in. (700 kilos per sq. cm.) in compression, and 2,845 lbs. per sq. in. (200 kilos per sq. cm.) in simple tension. In the cases of tension in beams, the extreme limit is 4,267 lbs. per sq. in. (300 kilos per sq. cm.).

(*c*)—For wooden members 1,138 lbs. per sq. in. (80 kilos per sq. cm.) is allowed for both tension and compression in the direction of the fibre.

(*d*)—In calculating compression members attention must be paid to obtain necessary resistance to crippling.

(*e*)—The maximum strains resulting from the combined effects of load and wind pressure, must not exceed the limits prescribed in the following cases:

Cases under Section 4, sub-heads *a*, 1 and 2
14,223 lbs. per sq. in. (1,000 kilos per sq. cm.)

Cases under Section 4, sub-head *a*, 3
9,956 lbs. per sq. in. (700 kilos per sq. cm.)

Cases under section 4, sub-head *a*, 4
8,534 lbs. per sq. in. (600 kilos per sq. cm.)

Cases under Section 4, sub-head *c*
1,280 lbs. per sq, in. (90 kilos per sq. cm.)

SEC. 5.—(*a*)—Bridges or viaducts the lengths of which between parapet ties exceed 65 ft. 7½ in. (20 metres), must be provided with special safety appliances for cases of derailment. The usual rail guards shall not rise

more than $1^3/_{16}$ in. (3 centimetres) above the rail, and they are to be placed within the track, at a clear distance of $6^5/_{16}$ in. (16 centimetres) from the rails. They should extend the entire length of the structure, their ends resting on the parapet ties.

(*b*)—The effects of temperature are to be provided for by means of movable ends. Provision must also be made for the free expansion and contraction of the floor system.

(*c*)—Hand rails must be provided for all bridges not over 2,625 ft. (800 metres) distant from the last switch point of a station provided with distance signals, or from a stopping place or a siding, and likewise for all such bridges as are not over 656 ft. (200 metres) distant from the center of a stopping place where train meeting points do not occur, and distance signals do not exist. Exception will be made for local railways, in so far that the limiting distance from stations with distance signals may be reduced to 328 ft. (100 metres) measured from their centers. Hand rails must be fitted without exception to all bridges over 65 ft. 7½ in. (20 metres) in length measured between parapet walls, and also on parallel retaining walls, when the latter are used.

SEC. 6.—(*a*)—For lines of unusually heavy traffic, for steam tramway lines, for standard gauge roads without steam locomotives, for roads of unusual track gauges, and also where building material of unusual quality is used, and in exceptional cases generally, the preceding regulations may be modified to suit each particular case.

(*b*)—For material not mentioned in section 4, such as stone, brick, lead, etc., and likewise for those constructive parts which are not portions of the main girders, trusses, floor beams or stringers, the assumptions must, as far as possible, be based upon experience and are subject to special approval.

SEC. 7.—The state authorities in order to be satisfied as to the rigid adherence to these regulations, may watch the construction of a bridge, and test the materials used at the company's expense.

SEC. 8.—(*a*)—Before a new bridge shall be opened to railway traffic, it is to be examined and tested by a special committee. The Railway Board of Inspection of Austrian Railways for this purpose will send a delegate as foreman of the Committee upon application received from the Railroad Company. The Railway Company will at the same time indicate the matters to be examined with reference to the respective certificates of approval. The written application is to be accompanied by the following information and plans:

1.—A diagram showing the composition of the trains to be employed in the test. These trains should, as nearly as possible, be productive of the same strains as the loads specified in Section 3 (or under Section 6). Trains must be placed on each track, and they shall be composed as follows, according to the length of the span:

For a span of 49 ft. 2½ in. (15 metres) or less, one locomotive, and a sufficient number of freight cars to cover it.

For spans of 49 ft. 2½ in. (15 metres) to 82 ft. 2⅜ in. (25 metres), two locomotives and cars to cover. The locomotives must be fully equipped

and of the heaviest class intended to run on the line in question. The cars must likewise be loaded to their full capacity.

2.—A statement based on calculation, of the percentage of the actual test load to be employed, as compared with the loads previously prescribed. Also a similar statement of the greatest elastic changes of form, under the influence of the test loads to be used.

(*b*)—The railroad company is to delegate a competent representative to assist at the examination and test. He is to be provided with the certificate of approval and plans in reference to the matters to be tested. The railroad company is to provide the trains to be used for this purpose, and also the required measuring appliances, for measuring the effects of loading.

SEC. 9.—(*a*)—Each bridge span must be tested with the load at rest as well as in motion. If several bridges of the same construction and of equal spans, not exceeding 32 ft. 9⅝ in. (10 metres) are to be tested, it is permissible to limit the trial tests to a part of them, provided the representative of the Railway Board of Inspection of Austrian Railways has declared the results of the tests of the first spans as sufficiently conclusive.

(*b*)—For the tests under the stationary load, the trains referred to under Sec. 8 sub-head *a*, must successively be brought to those positions by which the structure is most unfavorably influenced, and they must remain in those positions so long as the changes of form or deflections are observable. In the cases of truss or girder bridges freely supported, it will be sufficiently conclusive to load the bridge successively over half its length and over its entire length. Larger arch constructions must be loaded in the following two ways: First, the central portion alone; then the two end portions alone. For continuous girder bridges two trains are required for each track, sufficiently long to cover two spans. In order to test the piers and the girder portion above them, the continuous spans must be loaded over their entire length. For testing the centre of a span the load must successively be applied to the half span and to the entire span.

(*c*)—The trial under the moving load must be conducted in the following manner:

1.—A train composed in accordance with section 8, sub-head *a*, including however not more than two locomotives must be run over each track at first, at about a speed of about 12.43 miles (20 kilometres) per hour, afterwards the same to be repeated at a rate of speed of 24.85 miles to 31.07 miles (40 to 50 kilometres) per hour. These high speed tests may however be deferred until a later date in case the masonry has not become thoroughly set.

(*d*)—Bridges of two or more tracks must in all cases be simultaneously loaded on all of them. It is optional however to make tests previously by loading the tracks separately.

(*e*)—In case of local or traction railways, the high speed tests may be omitted.

SEC. 10.—The result of the examination and tests must be recorded, and the documents referred to in section 8 sub-head *a*, are to be annex-

ed. This registration is more particularly to show the particulars of the elastic or permanent changes, and to record the readings at fixed points. It must also state in how far the execution agrees with the approved plans. Finally the representatives of the Railway Board of Inspection of Austrian Railways is required to enter thereon his judgment as to the tested bridges and their fitness for service, or to forbid their use pending final disposition by the superior authorities.

SEC. 11.—(*a*)—Beside continued supervision, the railway companies must examine and test their bridges periodically, at least once in six years, following the rules laid down in section 9, sub-heads *b* and *d*.

(*b*)—The observation made and the result of each test, amount of elastic deflections, etc., are to be be kept separately for each bridge, and at the disposal of the Board of Supervision. In order to facilitate these examinations all bridges of more than 65 ft. 7½ in. (20 metres) length of span must be provided with permanently fixed marks previously to the first test, one at the centre of each span, and one at each of the ends, so that any deflection can at any time be determined.

(*c*)—Structures that have been subjected to examination and tests, must be reported to the Railway Board of Inspection as soon as any diminution in their strength has been ascertained. Otherwise objectionable features, not affecting the safety of the bridges may be reported at the end of the year.

SEC. 12.—No rolling load shall be permitted on a bridge which will strain it more severely, than that which has been made the basis of the calculations for its strength, without the special consent of the Board of Inspection. Nor is any rolling stock to be used which is heavier than that tabulated in section 3.

2.—*New Highway Bridges and Approaches.*

SEC. 13.—In regard to the examination and approval of plans for new viaducts over the railways, and such approaches as it is necessary that railway companies should build, the Ministry of Commerce will proceed according to the following rules (See sec. 14 and 17), which will also apply to the official acts of the Board of Inspection.

SEC. 14.—The approval of the plans for these structures shall be governed by the same regulations as those prescribed for bridges. (See sec. 1 and 19).

SEC. 15.—The calculations for stability must be based upon the dead load of the structure, and also upon two alternatives of accidental loading, viz:

(*a*)—The greatest possible number of vehicles upon the roadway, and simultaneously the greatest possible number of people upon the sidewalks and empty portions of the roadway.

(*b*) — The greatest possible number of people upon the sidewalks and roadway.

The most unfavorable of these two conditions must be considered in each case, and its effect on each part of the structure must be calculated.

All highway bridges will be subdivided into three classes according to the importance of the traffic which they are called upon to bear. The density of the human and freight loads will be scaled and assumed for the different classes as follows:

CLASS 1.—1—A human load of 94.21 lbs. per sq. ft. (460 kilos per sq. metre).

2.—A four-wheeled freight wagon of 13.23 net tons (12 metric tons), total weight, and 25 ft. 7⅛ in. (7.8 metres), in length, without pole. Width 8 ft. 2½ in. (2.5 metres), base of wheels 12 ft. 5⅝ in. (3.8 metres), gauge 5 ft. 3 in. (1.6 metres). A team of horses 23 ft. 7½ in. long (7.2 metres), weighing 3.31 net tons (3 metric tons).

CLASS 2.—1.—A human load of 81.92 lbs. per sq. ft. (400 kilos per sq. metre).

2.—A four-wheeled freight vehicle of 6.62 net tons (6 metric tons) total weight, 17 ft. 8⅝ in. long (5.4 metres), without pole. Width 7 ft. 10½ in. (2.4 metres), wheel base 9 ft. 2¼ in. (2.8 metres), guage 4 ft. 11 in. (1.5 metres). A team of two horses 11 ft. 9¾ in. (3.6 metres) long, weighing 1.65 net tons (1.5 tons metric).

CLASS 3.—1.—A human load of 69.64 lbs. per sq. ft. (340 kilos per sq. metre).

2.—A four-wheeled freight wagon of 3.31 net ton (3 metric tons), total weight, 15 ft. 9 in. (4.8 metres), long without pole, 7 ft. 6⅝ in. wide (2.3 metres), 7 ft. 10½ in. (2.4 metres), wheel base, gauge 4 ft. 7 in. (1.4 metres), and a team of two horses 10 ft. 6 in. (3.2 metres) long weighing 1.10 net tons (1 metric ton).

(*c*)—The influence of the wind must be considered in the manner defined in section 3, sub-head *f*, and the human and wagon loads must for this purpose be taken as a full rectangle in motion 6 ft. 6¾ in. (2 metres), high over the road level.

(*d*)—In addition to this the influence of changes of temperature must be considered, if the nature of the material calls for it, unless they are to be neutralized by arrangements prescribed in Sec. 5 sub-head *b*.

SEC. 16—The material under the influence of the loads specified in Sec. 15, sub-heads *a*. *b* and *d* shall not be strained per sq. in. of sectional area, beyond the limit herewith specified. Due allowance being made for rivet holes and other ineffective area.

(*a*)—For wrought iron under the conditions specified in Sec. 4 sub-head *a* article 5, 10,667 lbs. per sq. in. (750 kilos per sq. cm), with an addition of 28.44 lbs. per sq. in. (2 kilos per sq. cm), for each 3 ft. 3⅜ in. (1 metre) of span length. 12,802 lbs. per sq. in. (900 kilos per sq. cm), being however the maximum.

(*b*)—For cast iron the admissible limits of strain are identical with those fixed in Sec. 4 sub-head *b*.

(*c*)—Sec. 4 sub-head *a* articles 3 and 4 and article 5, sub-heads *c* *d* and *e* (see also section 6 sub-head *b*) concerning railway bridges apply also to highway bridges.

SEC. 17.—(*a*)—Completed viaducts and approaches before being opened to traffic must be officially examined with reference to the proper execu-

tion of the work, and compliance with the approved plans. For this purpose, application accompanied by the requisite documents must be filed with the Board of Railway Inspection, which will in each case determine without prejudice to further requirements of other competent authorities, whether, beside the examination, a test is to be made.

(*b*)—The completed bridges must also be examined periodically at least every six years. In case of necessity they must be tested, and if so the test must be in accordance with section 11 sub-heads *b* and *c*.

(*c*)—Vehicles causing a greater load upon the bridges, than that upon which calculation has been based, must not be allowed upon the bridge. A sign stating the greatest admissible load must be conspicuously displayed at the end of each bridge.

3.—Bridges already built.

SEC. 18.—(*a*)—All bridges now in existence must be entered on a tabulated register, which must contain at least the following information:

Location, date of opening for traffic, number of tracks, length of span, style of construction (deck or through), kind of material and name of manufacturer, greatest load actually used, deflections and other consequences, skew, if any, strains in material, also statement as to subsequent approval of original plans. Each railway shall have three months from the date of this publication within which to submit these statements to the Board of Railway Inspection. After due consideration, the Board will speedily take such measures as the observations made therein may suggest in the interest of public safety, or, in case the structures under consideration are located beyond its immediate control, it will submit its information to the Ministry of Commerce. The Board may in any case deemed necessary ask the company for additional information, plans etc., according to the character of the reports received.

The railway companies independently of these tabular reports and where such work has not been previously done, shall examine their bridges and test them with a train on each track, composed of the heaviest locomotives in use on the line operated, and of a sufficient number of the heaviest freight cars to cover the remaining part of the bridge. Other portions of this examination and test must be conducted strictly in accordance with the provisions of Section 11, and the result must be carefully preserved. Such examinations and test are to be commenced forthwith. In the case of an unfavorable result, or if the computations show that there is an excess of strain in the material over and above the maximum strains per sq. in. of effective section fixed in the following table, the railway company will report without delay to the Board of Inspection, accompanied by suitable propositions in reference to the matter.

These maximum strains are:

1.—For wrought iron in tension, compression or shear 13,512 lbs. per sq. in. (950 kilos per sq. cm).

2.—For rivets in shear 10,667 lbs. per sq. in. (750 kilos per sq. cm).

3.—For wood in tension or compression in the direction of the fibres

1,139 lbs. per sq. in. (80 kilos per sq. cm). For such parts of the bridge as are subject to both load and wind, the limits of admissible strains from both load and wind per unit of section may be extended as follows:

Case 1. 14,394 lbs. per sq. in. (1,050 kilos per sq. cm).
" 2. 11,378 " " " " (800 kilos per sq. cm).
" 3. 1,280 " " " " (90 kilos per sq. cm).

B—Highway Bridges and Approaches.

Railway companies shall furnish tabulated statements arranged as provided under sub-head *a* regarding highway bridges and approaches. It should particularly include all desirable data regarding the arrangement and width of roadway and sidewalks. It should also include the names of the officers controlling the roads, or of the board of supervisors in the district in which the bridge is located. In addition to these requirements the railway companies are to ascertain by conclusive proceedings the safety of their bridges with reference to the regular traffic to which they are subject. It will also be considered their duty to communicate with the Road Administration and the Board of Supervisors, in order to insure the maintenance of the cautionary measures, prescribed in Section 17 sub-heads *b* and *c*.

C—Examination by the General Board of Inspection.

The Railway General Board of Inspection of Austrian railways is authorized to subject to examination and test those railway bridges mentioned under sub-head *a* within its jurisdiction (Sec. 13), also the viaducts and approaches referred to under sub-head *b*. The board shall use its own judgment as to the extent of the test, and is to be guided by the preceding directions in regard to them.

4—Standard form of Reports.

SEC. 19—All the documents mentioned in sections 1 and 14, and referred to in 6, 12, 17, sub-heads *a*, *b* and *c*, and sec. 18 sub-heads *a* and *b* of these regulations, except plans, must be kept on sheets of the size of 8¼ by 13⅜ in. (21 by 34 centimetres).

(*b*)—Plans and calculations must be folded to the same dimensions, all other papers stitched, and everything furnished in double sets, one of which at least must be on such paper or linen and with such writing or drawing or duplicating material, as will insure durability in use.

(*c*)—After the final approval of all these matters and after all official acts in the sense of Sections 8, 9, 10, 17, sub-head *a* and 18 sub-head *c* have been accomplished, the signed duplicates will be returned to the railway company.

5.—Conclusion.

SEC. 20.—These regulations apply without any restriction to the administration of the business of a private railway company. For its application to lines pertaining to the Railway General Administration of Austrian State Railways, the following restrictions will take place.

(*a*)—Inasmuch, according to the ordinance of the Ministers of Com-

merce of June 23d, 1884, R. G. Bl.' 103 relating to the organization of the state railways,it is the province of the Railroad General Administration of Austrian railways, under the said minister's special authorization, to approve projects for new lines and for the reconstruction of lines under their jurisdiction, the approval of projects for new bridges, viaducts or approaches, or for the reconstruction of existing bridges, etc., is a part of the work of the board, and consequently the Sections 1, 14, and 6 in reference to these cases are considered void.

(*b*)—The official acts in the sense of Sec. 8, 9, 10 and 17 sub-head *a* will be executed by the General Administration of Austrian State Railways, assisted by a representative of the Railroad General Board of Inspection of Austrian State Railways, who shall be notified in due season, and provided with a full set of papers and plans prescribed in the present regulations.

(*c*)—When the Board of Inspection judges by the reports received that it is necessary in the interest of safe railway traffic that certain measures be taken,it will at once submit its proposition to the General Railway Administration of Austrian State Railways, reporting at the same time to the Minister of Commerce relatively to the case in question.

SEC. 21.—The present regulations will enter into force at the date of their publication, while simultaneously those of the Ministry of Commerce dated August 30, 1870, R. G. Bl. No. 114, and also those comprised in Section 21, 3 and 4 of January 25, 1879, R. G. Bl. No. 19 will be void.

Issued September 15, 1887.

APPENDIX 4.

THE MASSACHUSETT'S LAW

An Act relating to the Examination of Railroad Bridges in Massachusetts.

SECTION 1.—Every railroad corporation shall, when requested by the railroad commissioners, and at least once in two years, have an examination of its bridges and the approaches thereto made by a competent and experienced engineer, who shall report to the corporation the result of his examinations, his conclusions and recommendations, and the corporation shall forthwith transmit a copy of the report to the board of railroad commissioners. The first report shall be made and transmitted to the board not later than the first day of November in the year eighteen hundred and eighty seven, and subsequent reports shall be made and transmitted at intervals of not more than two years. When a railroad corporation builds a new bridge, it shall forthwith have a report in like manner made and transmitted to the board. The report shall furnish such information in such detail and with such drawings or prints as may be in writing requested by the board of railroad commissioners.

SEC. 2.—The board of railroad commissioners shall employ one or more competent experts to examine such reports, and may make such

further examination of the bridge structures as may be deemed necessary or expedient.

SEC. 3.—Nothing herein contained shall be construed to exempt a corporation from making other and more frequent examination of its bridges and the approaches thereto.

SEC. 4.—The expenses incurred by the board of railroad commissioners under this act shall be defrayed in the manner set forth in section twelve of chapter one hundred and twelve of the Public Statutes.

Approved May 31, 1887.

APPENDIX 5.

ACT PROPOSED BY ENGINEERS' CLUB OF KANSAS CITY.

DRAFT OF AN ACT TO PROMOTE THE SAFETY OF BRIDGES.

Be it enacted by the General Assembly of the State of Missouri, as follows:

SECTION 1.—It shall not hereafter be lawful for any public or private corporation, or for any person or persons building or rebuilding any metallic or wooden bridge superstructure of twenty or more clear feet span, in this State, to open such bridge for traffic, or permit it to be used, until such owner or owners shall have filed or caused to be filed, in the office of the Secretary of State, sufficient plans, strain sheets and statements of the strength of such bridge, together with a certificate under oath, given by some one of the "Bridge Experts" hereinafter provided for, upon a form to be approved by the Governor, showing that the said bridge has been proportioned to carry safely the maximum loads which can come upon it in its daily intended use; that it has been designed in accordance with the specifications which are recognized as standard among Bridge Engineers; that it has been built in strict accordance with said plans and strain sheets; and, if it be a highway bridge, that tablets or signs have been attached at each end, showing for what maximum loading it is abundantly safe.

SEC. 2.—It shall be the duty of each presiding county Judge, of the Mayor of any City, Town or Village in this State, of the President of each Railway or other corporation, and of each individual, owning or operating a bridge superstructure of metal or wood, of twenty or more feet clear span, in this State, to file or cause to be filed on or before the first day of January, 1890, in the office of the Secretary of State, a complete schedule and list of such bridge or bridges, giving for each, 1st, the location; 2nd, the character, whether metal or wood, and 3rd, the length of each span in each bridge.

And also further, to file by or before the 1st day of January, 1892, in the office of Secretary of State, sufficient plans, strain sheets and detail drawings to show the strength of said bridge or bridges, for each span thereof, together with a certificate under oath, from one of the "Bridge Experts" hereinafter provided for, upon a form to be approved by the Gov-

ernor, showing the uses to which said bridge is put; the loadings or weights which are imposed thereon, and the maximum strain in pounds per square inch, which result therefrom, upon the several parts thereof.

SEC. 3.—The Governor shall from time to time appoint, upon satisfactory evidence from skilled engineers, showing that the applicant, whether a resident of this or other State, possesses all the necessary knowledge, skill, qualifications and high professional character to perform properly his intended functions, a sufficient number of engineers, who shall be known as "Bridge Experts," and who shall exercise the exclusive right of certifying to the plans, strain sheets and statements pertaining to the bridges, open or to be opened to traffic in this state, as required in Sections 1 and 2 of this Act.

Such "Bridge Experts," shall file with the Secretary of State a bond in the sum of $5,000. with at least two sufficient securities to be approved by the Governor, which bond shall be renewed from time to time, as required by the Governor, properly to exercise their functions, and they shall take an oath faithfully, impartially, and carefully to perform their duties as such bridge experts.

They shall pay an initial fee of One Hundred Dollars each, and a further annual fee of Twenty-five Dollars each, which fee shall go into a special fund as hereinafter provided; and shall receive from the Governor a commission and license authorizing them to act as Bridge Experts for bridges in this State, until they resign, cease to pay their annual fees or are removed for cause.

Should at any time any one of such Bridge Experts prove remiss or unskillful, or make an official statement which proves to be erroneous, his commission shall be suspended by the Governor, pending investigation. Such investigation may be conducted as the Governor may appoint, and he shall have the power to withdraw permanently the commission of such Bridge Expert, without refunding any fees heretofore paid, upon becoming satisfied of the propriety of taking such action.

SEC. 4.—All initial and annual fees paid by the said Bridge Experts, as well as all special fines, collected from the owners or operators of bridges, as hereinafter provided, shall go into a special fund, to be known as the "Bridge Fund," out of which the necessary expenses of making investigations as hereinafter provided, shall be paid upon the warrant of the Governor.

SEC. 5.—A scale or schedule of maximum fees, which may be charged by the Bridge Experts for performing various services, shall from time to time be approved by the Governor, after consultation with such Bridge Experts, and they shall not be entitled to charge more than the fees so established by said schedule.

SEC. 6.—The Governor may, at his discretion, cause the plans, strain sheets and statements of the strength of the several bridges to be hereafter built or rebuilt in this State, as provided for in Section 1, to be checked over and examined by some other Bridge Expert than the one certifying to the same, and in case deficiences are found in the strength of said bridge or bridges, sufficiently serious in the opinion of the Governor to

warrant remedying them, it shall be his duty to notify the owners of such bridge or bridges of the facts, and to request them to remedy such deficiences, either in the building of the bridge, or within a reasonable time thereafter, and in case of non-compliance with said request the Governor shall report the case to the next General Assembly.

The Bridge Expert so employed by the Governor shall be paid out of the special "Bridge Fund" hereinbefore provided, such reasonable sum for his services, as the Governor shall approve.

SEC. 7. The Governor may also, at his discretion, engage the services of one of the Bridge Experts herein provided for, or some other engineer of his own choosing, to examine the plans, strain sheets and statements of strength provided for in Section 2, for the bridges heretofore erected in this State, or to make a special investigation of bridge superstructures which may be reported to him as unsafe.

And should any bridge structure in this State be reported at any time to the Governor, as being unsafe, it shall be his duty to cause one of the Bridge Experts herein provided for, forthwith to make an examination and written report thereon. Provided, however, that no such examination shall be undertaken until the informant has filed with the Secretary of State, a bond with approved securities, to defray all expenses and all resulting damages of such investigation, in case the allegations of such informant do not prove to be well founded.

Upon receiving the written report of the Bridge Expert so appointed, the Governor may, at his discretion, either direct the Secretary of State to collect from said informant under his bond, the full expenses and damages of such investigation, or he may direct the owner or owners of such bridge to pay the full expenses of such investigation; such collections in either case to be paid over to the Bridge Fund.

And in case any bridge structure in this State, is found to be unsafe, either by examination of plans or by special investigation, it shall be the duty of Governor to notify the owner or owners thereof of the facts, and to give them a reasonable time to make such structure safe, and in case of their neglect or refusal so to do, to report the facts to the next General Assembly.

The Bridge Expert or Experts employed by the Governor to examine the plans, strain sheets and statements filed under Section 2 for the bridges heretofore erected in this State, or to make special investigations of bridges reported to the Governor as unsafe, shall be paid out of the special "Bridge Fund" such reasonable sum for their services as the Governor shall approve.

SEC. 8. In case of any serious bridge accident in this State, and more particularly in the case of such accidents as involve the loss of human life, it shall be the duty of the Governor, immediately, to cause such accident to be investigated by one or more of the Bridge Experts provided for in this Act, and to have a written report made thereon, which report or reports the Governor shall transmit to the next General Assembly, with such recommendations as he shall deem proper. But nothing in this Act contained shall in any way modify or diminish the full responsibility of

the builder of such bridge or bridges, or of the owner or owners thereof, under the Statutes of this State or at the Common law.

SEC. 9.—The owner or owners of any bridge superstructure of twenty feet or more clear span, in this State, or other person or corporation, who shall fail to observe the provisions of this Act, and either to file the required lists and plans of bridges, or to make good deficiencies, or to make the bridge safe, as required by this Act, shall be liable to the State for the following per diem penalties for each and every bridge so long as failure to comply with this Act shall continue:

For non-filing plans, etc., required by Section 1, $10.00 per day.

For non-filing list, required by Section 2, $2.00 per day.

For non-filing plans, etc., required by Section 2, $10.00 per day.

For failing to remedy deficiencies, required by Section 6, $25.00 per day.

For failing to make bridge safe, required by Section 7, $100.00 per day.

To be collected by action brought by the Attorney General in the name of the State, before any Court of competent jurisdiction.

All fees, fines and penalties collected under this Act, shall at once be paid into the Bridge Fund, and be under the custody of the State Treasurer, who shall therefrom pay upon the Governor's warrant, the various expenses incurred under the authority granted in this Act.

SEC. 10.—This Act shall take effect and be in force from and after its passage.

APPENDIX 6.

ACT PROPOSED BY C. F. STOWELL.

An Act to Regulate the Building and Maintenance of Highway Bridges.

SEC. 1. There shall be in and for the State of New York a Superintendent of Bridges who shall be appointed by the governor, subject to confirmation by the Senate, and shall hold office for the term of five years from the date of such confirmation. He shall be a practical civil engineer, skilled in the theory and practice of bridge building, and of not less than ten years experience in such business. He shall not be interested either directly or indirectly in any manner whatever in any work or contract for the building or repairing of any highway bridge in New York state during his term of office. He shall have general charge of the building and maintenance of the superstructure of all highway, road and street bridges except such as are hereinafter exempted from the provisions of this act, and shall receive as compensation the sum of .... dollars per year, payable monthly. He shall not be engaged in any other business or avocation during his term of office.

SEC. 2. Whenever it may become necessary to build any new road or street bridge, or to make repairs to any existing bridge involving the changing or renewal of any parts other than the hand rail, planking or wooden joists, the highway commissioners or other local authorities hav-

ing charge of the work shall notify the Superintendent of Bridges, who shall thereupon furnish specifications for the work to be done, and in the case of a new bridge shall fix the moving loads for which the bridge shall be designed. He may also at his discretion furnish plans for the proposed work. If the proposed work is estimated to cost three hundred dollars or over, sealed proposals for performing it shall be invited by public advertisement in at least three newspapers published within the state for not less than four weeks prior to the letting of the contract, one of the newspapers to be designated by the local officials, having charge of the work and the other two by the Superintendent of Bridges, who, at the expiratiid of the time, stated in the public advertisement, shall open them and examine them to ascertain whether there are any which do not comply with the specifications, or specifications and plans, and such bids, if any, shall be marked informal. The bids shall thereupon be transmitted to the highway commissioner or other local authorities having charge of the matter, who shall award the contract to such bidder as they choose, rejecting however, all bids which may have been pronounced informal by the Superintendent of Bridges.

After a contract is awarded, and before the work is commenced, full detail plans shall be submitted to and receive the written approval of the Superintendent of Bridges, and a copy of such plans shall be filed in the office of said Superintendent of Bridges.

After the work has been performed under such a contract, and before payment therefor has been made, the Superintendent of Bridges shall examine the work to ascertain whether it complies with the specifications or specifications and plans furnished by him, and with the detail plans filed as heretofore provided, and if so he shall give to the contractor a certificate to that effect. No town board or other auditing board, officer or officers shall audit any claim for payment for work done under the provision of this act, unless there shall be attached thereto such certificate of the Superintendent of Bridges.

Whenever any piece of work covered by the provisions of this act is of a less estimated cost than three hundred dollars, the contract may be awarded without public advertisement, but all the other requirements specified for work of greater cost shall be fulfilled.

SEC. 3.—It shall be the duty of the Superintendent of Bridges to make and keep a correct list of all highway or street bridges in New York state, with a description of their length, width and material, date of construction and general condition, and for the purpose of making and keeping such a record all highway commissioners, or in their absence the supervisors of towns, and city engineers, or surveyors of cities or other local officers having charge of public bridges, shall furnish the Superintendent of Bridges with such information as he may require.

It shall be the duty of the Superintendent of Bridges to visit and inspect each and every highway or street bridge in New York state at least once every two years, and as much oftener as he may deem it necessary. Whenever in the judgment of the Superintendent of Bridges it is necessary to rebuild or repair any bridge to render it safe for public use, he shall

so notify the local officers having charge of the same, who shall thereupon proceed with such repairs or renewals in the manner hereinbefore specified, and until such repairs or renewals are completed the Superintendent of Bridges may, at his discretion, order such bridge closed to public travel.

SEC. 4.—It shall be the duty of all highway commissioners and other officers having charge of highway or street bridges to provide and erect at each end of each and every bridge, a sign not less than two feet square, upon which shall be painted in letters and figures not less than four inches high the heaviest load which can safely be driven over the bridge, which load shall be determined by the Superintendent of Bridges.

SEC. 5.—The Superintendent of Bridges shall have power to deputize one or more competent persons either temporarily or permanently, to perform any of the duties herein prescribed in case of the inability of said Superintendent of Bridges to perform said duties personally, either in consequence of physical disability, or of his being otherwise engaged in the performance of his duties. The Superintendent of Bridges is also authorized to employ such clerical assistance as may be necessary in the performance of his duties. He shall be provided with a suitable office in the new capitol, and with the necessary office furniture for the performance of his duties.

SEC. 6.—The Superintendent of Bridges shall report to the legislature annually on the first Monday in February, the condition of his department, a statement of the work done by it during the previous year, the expenses incurred thereby, and a report upon any accidents upon any highway bridges in New York state which may have occurred during the previous year, with the circumstances and causes thereof. The Superintendent of Bridges, his deputies and clerks, shall be repaid at the beginning of each month, upon the presentation to the comptroller of the proper vouchers, such sums as have been expended by him or them for necessary travelling expenses in the performance of the duties specified in this act. The total expense of this department shall not exceed the sum of .... dollars in any one year, which sum for the current year is hereby appropriated out of any funds in the state treasury not otherwise appropriated.

SEC. 7.—This act shall not apply to any bridge of less than fourteen feet clear span, nor to any bridge owned, maintained and operated by the state of New York, under the direction of the Superintendent of Public Works, nor to any bridge owned or maintained by any railroad, bridge or turnpike company, nor to any bridge owned or maintained by any corporation, firm or individual, and not on a public street or highway.

SEC. 8.—All acts or parts of acts inconsistent with the provision of this act are hereby repealed.

SEC. 9.—This act shall take effect immediately.

SOME PROBLEMS IN CITY ENGINEERING.

BY L. M. HASTINGS, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read May 20, 1891.]

The subject of this paper may appeal to many members of this Society, of whom some have in times past, served in the capacity of City Engineer, some are now struggling in that position, and still others it may be, are guilty of a lurking ambition to become the official engineer of some city or town. The first two of these classes will, I am confident, understand and appreciate some of the matters here referred to, while the latter class will, it is hoped, take heed and possibly warning by the experience and difficulties of others. Although many of the matters here referred to are not strictly engineering problems, yet they are, in a sense "problems in engineering."

Perhaps the first problem which will present itself to a city engineer, certainly one which will demand his thought at an early stage of his official term, is how to get along and accomplish the best results with the Committees, Boards, or Commissioners, to whom he is responsible, and under whose direction most of the public work is carried out.

A little experience will demonstrate that a vast amount of tact, firmness and good judgment, must be exercised to enable an engineer to carry out in a satisfactory manner, his plans, be they ever so well considered, simply from the interference or opposition of some person temporarily in authority.

I have known the reputation not to mention the moral character of the engineer to be severely tried by the persistence of some half informed committee-man who insisted that his plan and opinion should be followed rather than that of the engineer.

What increases this difficulty is the varying attitude and habit of mind of the same committee or board, as its personel changes from year to year. I have been surprised at the totally different treatment required at different times by committees. It is not enough that the plan itself should be worthy, if not properly presented and backed up, it may not receive the approval it deserves. The financial or political difficulties encountered in getting a proper plan adopted are often as great as the physical obstacles, met later, in its actual construction. To be successful in dealing with a City Government, the engineer must have a good degree of firmness, plenty of tact, and be about as close a student of human nature as he is of *Weisbach* or the *Engineering News*.

Another vital problem which presents itself to the city engineer is how to keep thoroughly informed on all the numerous branches of work presented in the wide range of city practice. He is called on to decide, or his opinion is asked, on so many diverse subjects, that keeping well up in the best practice, in all branches of the profession is essential, although well nigh impossible.

The tendency to make one branch a special object of study and research, works in some cases to the disadvantage of the general practitioner. A man feels diffident about expressing an opinion or recommending a plan, when the matter may be referred to an expert, who has made this particular subject a life study. This natural tendency to follow the lines of study and thought most congenial must be resisted to a large degree.

Thus, take a subject of the first importance to any city or town, its water supply,—what a temptation to study and explore all the many interesting and wonderful facts connected with water in its higher forms and uses, and in its mechanical, chemical, and sanitary aspects; or take the kindred subject of sewerage, etc., in all its many aspects and applications, the different methods of removing sewage, with all the patented and unpatented, and unpatentable contrivances, the methods of its treatment to render it innocuous to the public health, involving as it does a knowledge of chemistry, biology, michroscopy and kindred sciences, and, in the construction of sewerage works, a knowledge of mechanics and materials—here is a wide and inviting field for continued study and research, well deserving a man's best thought and endeavor.

To be competent to thoroughly and economically construct a good road with its appurtenances, drains, foundations, walls, bridges, etc., opens up a wide range of study and practice to which any engineer could well devote his whole time and attention. The problem of how to have a good working knowledge of the different lines of practice, resisting the almost inevitable tendency to become especially proficient in one branch, and correspondingly weak and inefficient in others, is not of easy solution.

Most of our technical schools and colleges are performing an excellent work in just this line, giving the student, unless he shall elect a special course of study—such a broad and generous training in the fundamental principles of engineering, and their application in general practice, as must be of inestimable service in after life—preparing him to become a good "all-round" engineer.

With or without the advantage of a college education, I believe that patient, judicious study, and careful, intelligent observation, will enable the engineer to keep well up with his work at all points.

Another problem of no small difficulty is that of being honest; and by "being honest" I do not mean simply refraining from taking what does not belong to one. It often happens that the city engineer is called upon to act as arbiter or referee between the city and a contractor, or to decide a disputed point between the city and a citizen, large interests often depending on the decision of the engineer. Now to be just with the city which employs him, and to be honest and fair with the "party of the second part," is often no easy matter. To do this requires not only engineering skill, but a sound, judicial faculty.

In cases contested in court, the city engineer often becomes an important expert witness, and to be honest there, avoiding the natural tendency and too common practice to give biased testimony, unduly favorable to the side which employs him, is not always easy.

This subject of expert evidence in the courts, has received considerable

attention of late, and was very ably touched upon by the late president of this society in his annual address.

The present practice in this matter is certainly one in which reform is needed. When summoned, I believe it to be the duty of an engineer to be particularly careful to give all the facts, whether favorable or unfavorable to the party by whose summons he appears, and to give such opinions only as these facts and his experience justify.

The neglect of these principles has already lowered the standing of the engineering, medical and other professions in the minds of the community. A keen sense of right and justice, and sturdy regard for the "whole truth and nothing but the truth," will enable the engineer to be honest with himself and all men.

Shall we not as engineers in solving these problems and over coming these difficulties, see to it that we are actuated by a sincere and conscientious purpose to do our whole duty, and faithfully and intelligently serve our fellow men.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

SEPTEMBER 9, 1891:—A regular meeting was held in the Club Rooms on Tuesday evening September 9th, with President Gobeille in the chair and twenty members present. The secretary being absent, Mr. C. M. Barber was chosen secretary pro tem.

The minutes of the last meeting were read and approved. Mr. Henry A. Barren and Mr. Perry L. Hobbs were elected active members.

The question of visiting day was brought before the meeting, and it was voted to place the matter in the hands of a committee who will continue during the current year, the committee to select the dates and make all necessary arangements.

President Gobeille then read a very interesting paper entitled "Straw and Corn on the cob as a fuel for domestic purposes." The paper was freely discussed, and the interest exhibited showed that the subject was very important as well as novel. After the discussion the librarian announced the receipt of several volumes of United States Coast survey reports for which the club is indebted to the courtesy of Col. Wilson. The club then adjourned.

CLARENCE M. BARBER, Secretary pro tem.

ENGINEERS' CLUB OF ST. LOUIS.

352d MEETING. OCTOBER 21, 1891:—The club met at 8 p. m. at the Washington University, President Burnet in the chair and twenty-nine members and six visitors present. The minutes of the 351st meeting were read and approved.

The executive committee reported the doings of its 116th meeting.

Messrs. H. P. Broughton, H. H. Humphrey, J. W. Nier and F. G. Schlosser were elected members of the club. Charles W. Stewart was proposed for membership.

Mr. John A. Laird then read the paper of the evening on the "Temporary Low Service Pumping Plant, St Louis Water Works." The paper contained a description of the principal details in the construction of the temporary pumping plant, including the incline, cradle, pumps, suction and delivery connections, boiler plant, etc. The shortest time of shutting down, breaking connections, moving the two cradles, making connections and starting up, with six men, was three hours. The paper was illustrated by views taken during the building of the third cradle, and followed by a series of views taken about the water works, along the conduit line and at the Chain of Rocks.

Discussion followed by Messrs. Johnson, Seddon, Laird, Russell, Burnet and Ockerson.

Adjourned. ARTHUR THACHER, Secretary.

WESTERN SOCIETY OF ENGINEERS.

284th MEETING. OCTOBER 7, 1891:—The 284th meeting of the Society was held at its rooms, Wednesday evening, October 7, 1891, at 8 p. m. President L. E. Cooley in the chair and some 35 members present.

The minutes of the previous meeting were approved. The secretary reported from the Board of Directors the following gentlemen elected to membership:

Messrs. John S Metcalf, James Macdonald, Frederick Sargent, Edward S. Wills, Chas. P. Kemble, Carl E. Davis, Jonathan Phillips, F. W. Settan, Lightner Henderson, Arthur S. Coffin.

Proposed for membership: Prof Chas. B. Wing, G. P. Faucon, Geo. B. Weston

The president called the attention of the Society to the By-laws which were proposed at the last meeting and were printed in the proceedings, and which are to be voted upon at the next meeting.

Before calling for reports of Committees, the secretary explained what had been done in regard to the matter of Topographical Map and Economic Geology of Illinois at the Columbian Exposition, 1893, for which a committee was requested at the last meeting. He had called upon the Illinois Commission, at their office in the city, who at the time were discussing the question of Topographical Survey, and made an appointment for the Committee of the Society to appear before the Commission.

Mr. Chanute, chairman of the Committee on Bridge Legislation, then presented and read their report. (This report with its appendices is given in this issue of the Journal.)

PRESIDENT COOLEY:—Gentlemen, I think we have listened to one of the most valuable reports ever presented to this Society, in regard to a very important subject. The Committee has suggested therein a certain line of action, but I suppose before any action in the matter is to be brought definitely before the Society, Mr. Williams' draft of a law has to be presented.

Before the reading of Mr. Williams' bill, Mr. D. C. Cregier asked to be allowed to present a matter. The order of business was then suspended.

MR. CREGIER:—I desire to say to this Society that there is a movement on foot in this City to rear a monument in memory of a very distinguished engineer, and I have been invited to personally talk up an interest in the matter. I suggested to the gentleman who had promised a very generous sum towards it. that it might be a good thing for this Society to take charge of the matter—to have this monument put in one of the parks, and the project carried out under the auspices of this Society, and he very readily assented to the suggestion. The deceased man to whom I refer is Captain John Ericsson, a man, in my judgment of great genius, and whose memory, in my humble opinion, should be preserved in some marble or bronze tribute; for I verily believe that he belongs among those who have contributed largely towards the perpetuation of this great Union and moreover his genius was bestowed in a way that the engineers of this city ought to take hold of the proposition. I bring it up in this way to learn whether the Society would act as agents, if you please. I think it would be entirely appropriate to do so, and I would like to hear from gentlemen present whether they think it would be proper. It involves no responsibility at all; it is only a question of appropriateness.

A cordial acquiescence in the project being manifested, Mr. Cregier said: In order to bring the matter formally before the Society, I move you sir, that a special committee of three or five as it may suit the chair, and to be selected by the president, be appointed to take this matter under consideration and report back, if you please, their views to this Society, whether they think it is wise, appropriate and paper. I myself believe that it is entirely appropriate, and this Society is the proper one to take charge of the matter. I make that motion.

The motion was seconded by Mr. Chanute, and carried unanimously.

The president appointed as chairman of the committee, Mr. DeWitt C. Cregier, and hoped he would take active charge of the project and suggest to the chair his own colleagues on that committee to carry it through.

Mr. W. E. Williams was then called and presented the following:

A BILL FOR

AN ACT to Provide for the Appointment Qualification and Duties of Deputy State Engineer, and to Provide for the Construction and Maintenance of Highway Bridges in the Interests of Public Safety.

SECTION 1.—Be it enacted by the people of the State of Illinois represented in the General Assembly, that the Governor may appoint, by and with the advice and consent of the Senate, and commission as Deputy State Engineer, as many persons as shall make application having the qualifications of electors in the State in which they reside, who are practical Civil Engineers, skilled in the theory and practice of Bridge building, and of not less than 5 years experience in such business, and they shall not be interested directly or indirectly in any manner whatever in any work or contract for the building or repairing of any Highway Bridge in the State of Illinois during his term of office.

SEC. 2.—No person shall be appointed a Deputy State Engineer except upon petition of at least fifty legal voters of the State of Illinois, one-half of whom shall be resident free-holders, and upon the presentation of a certificate setting forth that he is qualified for said office, issued by the Railway and Warehoue Commission, of the State of Illinois.

SEC. 3.—Each Deputy State Engineer so commissioned, shall hold his office for the term of four years, unless sooner removed by the Governor.

Before entering upon the duties of his office he shall give bond, payable to the "People of the State of Illinois" in the sum of $5 000 with sureties to be approved by the Governor, conditioned for the faithful discharge of the duties of his office, and shall take and subscribe the oath of office prescribed by the Constitution.

The oath and bond shall be deposited in the office of the Secretary of State. The Secretary of State may grant certificates of Magistracy of Deputy State Engineers, which certificate shall be under his hand and great seal of the State. The fee for such certificate shall be 25 cents.

A Deputy State Engineer shall have authority to execute the duties of his office throughout the State.

SEC. 4.—Whenever the officers of any municipality in this State desire to build or let the contracts for any bridge structure of span exceeding twenty (20) feet clear span, they shall submit the plans, specifications and contract proposed to the inspection of a Deputy State Engineer, who shall examine the plans, specifications and contract with reference to the safety of the proposed structure, and also as to the economic points involved. And he shall report to said officers the approval or rejection of the plans proposed, together with such recommendations concerning the same as he shall think proper.

A copy of said report, together with copy of said plans, specifications and contract shall be filed with the county clerk of the county where said proposed structure is located.

SEC. 5.—In case said Deputy State Engineer shall reject said plans as being unsafe for the place and purpose intended, it shall be unlawful for said municipal officials to build said structure or pay for any part of the same out of the funds of said municipality.

SEC. 6.—In case the structure proposed to be built, in the opinion of the Deputy State Engineer, who examines the plans proposed, requires that the material for said structure should be tested before it is delivered at the place of erection, either in the shop where manufactured or at other suitable place, he shall so recommend and set forth the test or tests required, and said municipal officials who contract for said structure, shall employ a Deputy State Engineer to make said tests, and the contractor for said structure shall present to said municipal authorities the certificate of said Deputy State Engineer making said tests, setting forth the result of said tests and that they fulfill the requirements therefor before said contractor shall be permitted to commence the erection of said structure. Said certificate shall be placed on file with the plans of said structure as provided herein. It shall be unlawful for said municipal officials to pay for any material which is rejected as not meeting the requirements of said tests.

SEC. 7.—Upon the completion of any bridge structure, the plans of which have been approved as aforesaid, the said municipal officials shall secure the services of a Deputy State Engineer, who shall examine the same, and see that the plans, specifications and contracts aforesaid have been complied with, and shall report

for the acceptance, rejection or modification of said work, so as to conform to the contract aforesaid, which report shall be placed on file with the county clerk of the county provided herein.

SEC. 8.—It shall be unlawful for any municipal official to pay for, out of the funds of the municipality, any bridge structure reported as unsafe by said Deputy State Engineer

SEC. 9.—It shall be the duty of the municipal officials who have charge of the construction and maintenance of Highway Bridges within this state, to employ, within two years from the passage of this Act, and as often as every succeeding two years thereafter, a Deputy State Engineer to examine the Highway Bridges of span exceeding twenty (20) feet, within their jurisdiction and report upon the safety thereof, which report shall show the character of the structure examined, and its abilty to stand the service required of it, together with such information and recommendations as said Deputy State Engineer may think proper or said municipal officials may require, which report shall be placed on file with the county clerk as provided in this act.

SEC. 10.—In case the municipal officials aforesaid shall fail to provide for the examination of the bridge structures as herein provided, or shall fail to make safe or close the travel on any structures reported as unsafe by said Deputy Engineer, or shall fail to placard the said structure, setting forth the maximum load it will carry safely, which placard shall be in full view at each end of said bridge, and with letters not less than four inches high, and an accident occurs to the injury or loss of the life or property of any person, the said municipal officials shall be personally liable to the parties so injured. But this shall not release the said municipality from its liability in such case.

SEC. 11.—The fees for the services of the Deputy State Engineer may be as agreed upon by the municipal officials and the engineer, but in no case shall they exceed the maximum schedule of prices fixed by the Railway and Warehouse Commission.

SEC. 12.—The Railway and Warehouse Commission shall, from time to time, fix a maximum schedule of prices for the several classes of service the Deputy State Engineer shall perform.

After Mr. Williams had explained the principal features of his bill, Mr. Strobel moved that the report be accepted and printed. Carried

No discussion of the report was called for it having been thought best to await the distribution of the matter among the members.

The secretary next presented some further discussion on Mr. Corthell's paper on a Deep Waterway between the Lakes and Atlantic Seaboard, but it was decided, at the president's suggestion to postpone the reading until an evening could be given to it, or until it could be printed for further discussion under the supervision of the Board of Directors of the Society.

The secretary then read a valuable paper on "PRACTICAL TESTS OF COMPOUND LOCOMOTIVES," by Mr. C. H. Hudson, member of the Society, General Manager of the E. T., V. & G. R. R., which was published in the October issue of the Journal.

After some remarks by Mr. Raeder upon the progress of the building project and a criticism by Mr. Thos. Appleton on the annual summer meeting an adjournment took place

JOHN W. WESTON, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.
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This Association, as a body, is not responsible for the subject matter of any Society or for statements or opinions of any of its members.

FOUNDATIONS AND FLOORS FOR THE BUILDINGS OF THE WORLD'S COLUMBIAN EXPOSITION.

BY A. GOTTLIEB, MEMBER WESTERN SOCIETY OF ENGINEERS.

[Read November 4, 1891.]

As Chief Engineer of the World's Columbian Exposition, it was one of my duties to design and devise the foundations for buildings, and determine the strength and mode of construction of floors for the various buildings. The execution of every engineering project involves right from the start the solution of two problems; the achievement of the object by satisfying all physicial and mechanical requirements, combined with the least necessary expenditure of money. It is the province of the engineer to determine how much of material and labor, and what kinds of each, must be employed to accomplish the desired end, and what the proper economy shall be in each individual case. His knowledge and experience will guide him to determine these points, according to the circumstances governing the case, the object of the work, and the means at his disposal.

The World's Columbian Exposition, as is well known, will be at Jackson Park, one of the Public Parks of this city, the use of which was granted under the express condition, that all buildings erected there must be removed after the Exposition closes, and the Park restored to its original condition. This means in other words, that the buildings will be in actual use for six months only, and then removed, being temporary structures in the strictest sense of the word. This fact naturally must be considered in the plans devised, as after six months use, the bulk of the material must go to waste. The vast area to be covered by buildings (over 100 acres) required more care with reference to economy, than is necessary in ordinary sized buildings, as any needless expense multiplies itself so enormously in those extraordinarily large surfaces.

The natural formation at Jackson Park before the grading was done, was mostly low ground from + 0.5 to + 11 feet above city datum; the average for about 300 acres was + 3.5 feet. The southern and the eastern parts were the lowest, the western part being the highest ground. City datum is the low water line of 1847, and the stage of the water in the lake for the last year was about one foot above datum. The highest stage ever observed for the last fifty years was four feet above datum, except occasional tidal waves.

By excavations from the high ground, and dredging of lagoons, material has been obtained to fill up the low grounds so, that the grade under buildings is at least five feet above datum, and the ground outside of buildings six feet above datum, with the exception of the terraces around the buildings, and the lake shore drive, which are from 10 feet to 12 feet above datum. The material of the fill is sand throughout. Borings in various parts of the grounds show the formation to be very uniform, as follows: About five to eight feet sand; four to ten feet quicksand; six to ten feet soft clay; six to ten feet clay; and then hardpan. The average depth below surface of the hardpan is from 26 to 36 feet. An exception to this is to be found in the higher locations, where the top layer of sand has a greater depth, and in the northwest corner of the Agricultural building, and the southern half of the Manufacturers and Liberal Arts building, where deep mud holes prevail, hardpan 30 to 45 feet below surface.

I had first intended to have pile foundations under all buildings, and piles driven for the floor supports. Before this was adopted, however, test piles were driven in different locations, partly to hardpan and partly to a lesser depth, and heavily loaded with sand. At the same time platforms of 3 inch planks were constructed, placed in different locations, on top of the sand, and loaded uniformly with pig iron, about 2¼ tons per square foot. These platforms were loaded gradually, and the settling carefully noted under each load. The loads remained for several days and were then transferred to other platforms. It was found that under the maximum loading the settling was very small, about ⅜ of an inch, and very uniform, and that after this settling had once taken place, the increase of load up to 2¼ tons per square foot, caused no perceptible increase in settlement.

Platforms loaded on top of sand filling, over the mud holes above referred to, sank from one to three feet under a load of 1½ tons per square foot, and kept sinking the longer the load remained on. It was thereupon determined to use pile foundations in these locations, and everywhere else where the formation was favorable, platform foundations so proportioned, that under a maxium load from buildings or from floor loads, the pressure upon the ground would not exceed 1¼ tons per square foot.

These platform foundations consist of 3 inch pine or hemlock planks, with blocking on top, to distribute the pressure from loads uniformly over all the planks, and to furnish support for the posts, which carry the caps supporting the floor joists and posts of the buildings. The blocking was to be well spiked to platform planks and posts, and caps and sills drift-

bolted. The general floor loads for the various buildings were adopted as follows:

Fisheries Building	100 lbs. per square foot.
Manufacturers and Liberal Arts Building	100 lbs. per square foot.
Agricultural Building	100 lbs. per square foot.
Machinery Building	200 lbs. per square foot.
Electricity Building	100 lbs. per square foot.
Mines and Mining Building	150 lbs. per square foot.
Machinery Annex	200 lbs. per square foot.
Horticultural Building	100 lbs. per square foot.
Women's Building	100 lbs. per square foot.
Transportation Building	150 lbs. per square foot.
Galleries	80 lbs. per square foot.

These are general floor loads only, intended for the aisles in the buildings, and for the lighter exhibits of each branch. Where heavy exhibits, machinery or tracks were to be located, the supports and floors to be re-inforced as required, when the weight and character of the exhibits, and their exact location in the buildings will be known.

In proportioning the sizes of foundations and floors, to resist the maximum strains from above loads, I have recommended to adopt the following unit strains: For bearing of vertical posts upon underlying blocking (head or end of fibre upon transverse fibre) 600 pounds per square inch.

Tension in extreme fibre in caps and joists, 1,500 pounds per square inch.

Notices appeared in the Daily Press injurious to the interests of the Exposition, as well as to myself, claiming that the foundations of buildings were too weak, and had to be re-constructed at great extra expense. Such statements were eagerly taken up by papers unfriendly to the enterprise, and enlarged upon in every conceivable manner.

I have abstained from entering into any controversy, believing that the daily newspapers are not the place to settle such questions. I hold that such professional men, as compose our Engineering Societies, are the best and most competent judges in such matters, and that it is my duty, as an Engineer, to lay before them for their discussion, such information and reasoning as caused me to adopt the course I did, and which I am ready to defend.

Having for the last twenty-five years been engaged in the building of bridges, trestles, roofs and other structures of steel and iron, as well as of timber; and having seen the time when wooden bridges were used almost exclusively on the railroads of this country, I may claim to know something of the material used, from my own observations. Railroad bridges and trestles are subjected to the severest strains possible, more so than any other kind of construction. The maximum load for which they are proportioned, is sure to pass over them many times each day, sometimes many times each hour; the speed with which these loads pass over the structures is so great, that the effect is vastly greater than it would be from a static load. Professor Weyrauch has demonstrated by experiments, that

a rapidly applied load, quickly removed, has double the effect of a static load. Consider in connection with the load and speed, the unavoidable imperfections in the track and rolling stock, and it will be conceded that the utmost care in the selection of material, and in the framing and building up of the same must be exercised, and the largest practicable factor of safety used in proportioning the members of such structures; particularly such as receive a direct shock from the passing loads, as the lower chords of bridges, when supporting floor beams and track stringers, and the floor beams and stringers themselves. If the parts mentioned are of wood, as in Howe Truss Bridges and trestle work, two more factors require due consideration. While iron and steel members are the strongest when new, the reverse is true of timber as generally used in large structures. The timber is more or less green or unseasoned, and consequently not as strong in the first period of its actual use, as it is a year or two after it has been seasoned in the open air. (I will show later from experiments by Professor Lanza, what the relative strengths of green and seasoned timbers are.) And yet these structures must be strong enough the first day after their completion, to do their duty.

The second most important point to be considered is that wood is a perishable material; its exposure alternately to the influences of the sun's rays and to moisture, from rain and snow, causes the same to crack and rot, and so materially weakens its strength until in a comparatively short time, from seven to ten years, if unprotected from the above mentioned agencies, it becomes entirely unfit for use and must be replaced with new parts.

While it is easy to protect metal parts of structures against destruction from corrosion by properly painting the same, this remedy will not apply to timber. New timber if painted, will be destroyed quickly by rot, as the coat of paint prevents the evaporation of the moisture contained in the wood fibre from its growth; and if painted later, when the timber has been exposed, rot has usually already set in, particularly in joints, between keys and sticks. There is but one way to preserve timber, and that is by seasoning the same either in the air or by steaming, and preventing the moisture so eliminated from re-entering again. This can be obtained either by covering the structures, so as to exclude the sun and moisture, or by treating the wood by some preserving process. The principle involved in all wood preserving processess, is first the seasoning of the timber by steaming, thereby removing the moisture from the crevices, and then filling the crevices by some substance, which will prevent atmospheric moisture from re-entering.

I had occasion to examine wooden railroad bridges, covered on top and sides, which had been in actual use for more than twenty years, without having a single member replaced by a new one, and where the timbers were sound and perfect. Another remarkable fact I will mention in connection with these old covered bridges, that the lower chords having been proportioned for the lighter loads customary in those days, were strained more than two thousand pounds per square inch, under our modern rolling loads, without any allowance for impact, and stood all this

without apparent injury. The ultimate resistance of white pine and spruce against tearing, as given by various authors, is 10,000 to 13,000 pounds per square inch. Professor Rankin in his "Applied Mechanics" gives it as 12,400 pounds.

Considering the two characteristics of timber above mentioned, it was customary to adopt as a working strain for tension members, and extreme fibre strains in beams, one thousand pounds per square inch, or use a factor of safety of ten. If the increment of stress, caused by the impact of a moving train is taken into account, that strain is probably increased to 1,500 pounds per square inch. Thousands and thousands of such bridges were built and did excellent service for a quarter of a century; and although our railroads, with their increased traffic and heavy rolling stock, have replaced most of the old wooden bridges with modern iron or steel structures, still I venture to say there is scarcely a road in this country that has not one or more of the old structures yet in actual daily use; and many a member of our society will bear me out in that.

The tests by which the tensile resistance of woods were determined, were of course, made on small specimens, as it is impracticable and difficult to test large sized pieces of timber for tension. Necessarily the results must be larger, than if derived from tests of full sized pieces, as the small pieces do not contain as many imperfections, as always occur in larger sizes. This was one of the reasons, why in practice such a large factor of safety was adopted. Later and recent tests to determine the modulus of rupture and modulus of elasticity, by loading beams with transverse loads, have been made by Professor Thurston, Laslett, Col. Rodman and others, mostly also with small sized pieces. On full sized beams valuable tests were made by Professor Lanza, of the Massachusetts Institute of Technology, and also a member of our own society, Mr. Onward Bates. I shall proceed to review the results of some of their tests and their application to the case I treat upon.

The mean moduli of rupture of spruce beams as determined by various authors is as follows:

Hatfield	9,900 pounds per square inch.
Rankin	11,100 pounds per square inch.
Laslett	9,045 pounds per square inch.
Trautwine	8,100 pounds per square inch.
Rodman	6,168 pounds per square inch.

Col. Rodman's tests were made with larger sizes, hence the smaller results than the others.

From tests made by Professor Lanza on full sized joists of spruce from 2 × 12 and 15 feet length and less, loaded in the middle and at other points, the modulus of rupture varies from 2,828 pounds to 7,626 pounds per square inch; with an average of 5,046 pounds derived from sixty-eight experiments. The average modulus of elasticity was 1,332,451 pounds. Four tests were made with seasoned sticks; two of them had been seasoned for four years on the wharf, and showed moduli of rupture of 8,748 pounds and 7,562 pounds, and two were seasoned with steam heat in the

labaratory for six months, and gave moduli of 7,448 and 7,211 pounds, or about forty-five per cent. larger than the average modulus for unseasoned timber. According to Professor Lanza about the same modulus of rupture should be used for white pine as for spruce. In another table Professor Lanza gives the result of tests with beams varying in size from 4x12 to 6 x 12 all twenty feet long, in time tests, where the loads remained on the beams for sometime, and while so loaded were seasoned by steam heat in the labaratory. Of six beams five were green timber at the beginning of the experiment, while the sixth piece had been seasoned on the wharf for six months. The average modulus of rupture for the five pieces was 6,337 pounds, while the modulus for the sixth piece was 8,547 pounds, or about 35 per cent. larger than the green pieces. In another time test with spruce beams all 18 feet long, seasoned for six months in the labaratory, not loaded during seasoning, the average modulus of rupture was 7,300 pounds per square inch; modulus of elasticity, 1,600,000. All these moduli of rupture are smaller than those obtained by other authorities from tests with smaller pieces, but they are more reliable; besides they prove that seasoned timber will stand more strain than green timber from 30 to 45 per cent. according to circumstances. Commenting upon the results obtained from his experiments, Professor Lanza correctly remarks, that while it was necessary to use larger factors of safety, when the moduli of rupture were determined from tests with smaller pieces, it will be sufficient for most timber constructions, except in factories, to use a factor of four. For breaking strains of beams he also states most properly, it is better engineering to determine as the safe load of a timber beam, the load that will not deflect it more than a certain fraction of its span, say about 1-300 to 1-400 of its length.

Mr. Onward Bates, engineer of bridges of the C. M. & St. P. R. R., made a series of tests with wooden track stringers in order, as he states, to determine the strength of same, under nearly as possible, the same conditions, as when in use in the bridges. By this Mr. Bates means, of course, the mode of loading without considering the effect of the momentum of a running train. The tests were made with wooden stringers, partly new, partly taken from existing bridges and trestles, after having been in use for several years. The beams were supported at both ends, and a load or pressure applied in the middle of the span, until the timber broke. Of forty test pieces fourteen were new timber, not used before, and twenty-six were stringers taken from existing bridges, where they were used from 3½ to 8½ years, in the average for 6.2 years each. In his brief review of tests Mr. Bates remarks, that stringers which have been long in use are, as a rule, badly season-checked along the middle of the depth. He arrives at the following conclusions:

1st. Green timber is not as strong as after it has seasoned.

2d. Age and. use does not weaken the timber. It preserves its strength until weakened by decay.

3rd. Knots do weaken the timber seriously, both in reducing the effective section of the beam, and in causing the fibre to be curly and cross-grained.

4th. While age does not weaken the timber itself, it weakens it by season cracking.

Mr. Bates finds from the forty tests of pine stringers, the average modulus of rupture to be 3,906 pounds per square inch (against 5,045 pounds by Professor Lanza's experiments on sixty-eight pieces of spruce; and 4,451 pounds on thirty-seven pieces of western pine,) all green timber; and a modulus of elasticity of 1,123,090 (against 1,332,451 of Professor Lanza from green timber). In concluding his paper (contained in the transactions of the American Society of Civil Engineers of 1890), Mr. Bates remarks that his paper contains nothing about the fibre stress, which should be permitted. Given the loads and strength of material, the engineer who builds a bridge must decide the amount he will strain the latter.

I would add to this, that if the structure to be built is not a railroad bridge, the fibre stress to be permitted will also be determined by the engineer, according to the use and purpose the structure is intended for.

From the standard plans of wooden trestles, published in connection with Mr. Bates' paper, and the locomotive diagram contained in one of the bridge specifications of the C. M. & St. P. R. R., 72,000 pounds on three pairs of drivers with six foot wheel base, I compute that Mr. Bates uses a fiber strain of 888 pounds per square inch in track stringers, (including dead load, but without considering the impact), which under a train moving with a speed of 20 to 40 miles per hour will increase that strain to from 1,100 to 1,332 pounds (25 to 50 per cent.), and that the deflection under the static load, of 16 foot track stringers will be .3 of an inch, using the modulus of elasticity, as determined by his experiments. As to the conclusions arrived at by Mr. Bates, I will say the following: Of the forty pieces tested, twenty-six were old timbers having been exposed to the weather, and to heavy strains from running trains for 6.2 years on an average, some of them even showed already signs of decay, most of them were badly season cracked as Mr. Bates calls it. I venture to say that those cracks were caused as much, if not more, by the heavy strains to which those timbers were constantly subjected for so many years, as to the seasoning agencies. It must be clear that such timbers are not fair samples to determine neither the strength nor the elasticity of seasoned timber, not used before testing, and to furnish a reliable guide for future constructions. The test results of the experiments themselves bear out the correctness of this statement. While Mr. Bates acknowledges by his first conclusion, that "green timber is not as strong as after it is seasoned," the results of his tests do not warrant such a statement, if he considers the twenty-six old pieces as equivalent to "seasoned timber." I find that the average modulus of rupture of the 14 new sticks is 3,960 pounds, while of the twenty-six old pieces the average was only 3,874 pounds. I also hold that the loading of the *old* stringers with a heavy center load, was more injurious to them, than it would have been even to green timber, for timber, at the best, is not as homogeneous a mass, as metals are, and the severe cracking in the center, which most of the old sticks showed to considerable extent, did certainly not require as much pressure to increase the cracks and cause the pieces to fail sooner than they would have

if new, or seasoned in the ordinary way, without being exposed to heavy loading and the influence of the weather. In order to determine the strength of our merchantable pine timber, as we obtain it from our lumber merchants, I had thirty-three pieces furnished to me by one of the lumber yards of this city, and tested in the Government Testing Machine in the Watertown Arsenal.

The pieces were 3″ × 3″ pine with small knots in them and were cut from 3 × 12, 3 × 14, 3 × 6 and 6 × 8 timbers, by the lumber men, without any special directions from me, selected from the stock on hand without any particlar care. The test pieces were turned down in the middle to a diameter of one inch. The first nineteen pieces were from green lumber sawed this year; the last fourteen pieces were from yard seasoned material. The ultimate resistance in the nineteen green pieces was from 5,270 pounds to 9,660 pounds per square inch, with the exception of two pieces, which were defective; average for all nineteen pieces 6,681 pounds per square inch. If the two defective pieces are omitted the average is 7,289 pounds. For the seasoned pieces the ultimate resistance varied from 6,640 pounds to 10,210 pounds, one piece defective, average 7,720 pounds per square inch. If the one defective piece is omittted the average is 7,994 pounds. At the same time I obtained from the test records of the Arsenal an abstract of tests made in 1883 with pine blocks, tested with pressure across the fibre. The indentation produced at the surface of the timber with a pressure of

846	pounds	per	square	inch	was	0.01	inch.
1,000	"	"	"	"	"	0.02	"
1,077	"	"	"	"	"	0.03	"
1,121	"	"	"	"	"	0.04	"
1,153	"	"	"	"	"	0.05	"

From which it will be seen that a pressure of 600 pounds per square inch would produce an indentation on the blocks under the posts of the foundations of less than 1-100 of an inch. It is needless for me to say anything more upon this point.

Coming back to the statement of Professor Lanza, that it is better engineering to proportion floor beams with reference to their deflection, than to the ultimate strength, I have computed the deflection of a 2″ × 12″ joist, 14 feet between supports, if loaded so as to produce a fibre strain of 1,500 pounds per square inch, using the modulus of elasticity of Professor Lanza 1,332,451 for green timber, and find the deflection to be 0.63″ equal to 1-270 of the length, with the modulus as found for material seasoned without being subjected to loads, being 1,600,000, the deflection would be 0.45 of an inch, equal to 1-370 of the length.

Most of the spans of joists in the Exposition Building are from 11′ 6″ to 12′ 6″ length; some few exceptions are over 14 feet length.

In recapitulating, I will briefly summarize the result of the various tests, and the conclusions I have arrived at.

1st. That the use of spread foundations upon the sandy bottom with clay substrata, as adopted, were warranted by the tests made with loaded platforms.

2nd. That the adoption of a strain of 600 pounds per square inch for pressure of posts of foundations upon the blocking timbers, producing an indentation of less than $^{1}/_{100}$ of an inch would be justified even for permanent structures.

3rd. That the timber in floor joists and caps of posts, under the circumstances mentioned, must be considered as timbers seasoned, at the time when they will be called upon to do service; and seasoned without being subjected to loading.

4th. That by using a working strain of 1,500 pounds per square inch in the parts above named, if the tests results of Professor Lanza, for seasoned timber are accepted, a factor of safety from 4 $^{8}/_{10}$ to 5 $^{9}/_{10}$ is obtained; that if the results of the Watertown Arsenal are accepted, the factor of safety obtained from the 14 seasoned specimens show a factor of safety of 5 $^{1}/_{10}$. If the test results as given by Trautwine, Rankin, Hatfield and Laslett are accepted, the factor of safety would be still larger

I will not omit stating that the question has been raised, whether such material as has been specified in the specifications could be obtained in such large quantities, as the immense buildings will require, and considering the time in which it will have to be furnished. I do not believe the point well taken. The specifications require sound white pine, free from wind shakes, rot and other defects impairing the strength of the timber, that only small and sound knots be accepted, and that small sap angles will be allowed in sizes over 12 inches. Such material has been growing for centuries, is growing to-day, and will in the future. A little care in selecting the material will furnish it; but if it should have been found impossible, considering the shortness of time, the remedy would be simple, and has been adopted to my own knowledge often enough with steel or iron. If the material specified could not be obtained in quality, the contractor was allowed to substitute other material, increasing at his own expense the quantity to compensate for the deficiency in quality.

At the time of my resignation it had been ordered, without my consent, to increase the size of timbers in foundations and floors to such an extent. as to reduce the pressure of posts upon blocking from 600 pounds per square inch to 400 pounds; and the fibre strain of joists and caps from 1,500 to 1,200 pounds per square inch; the foundations were re-inforced as it was stated. It will not be necessary for me here to elaborate upon the fact, that in trying to solve the problem before me, I did not consider how to re-inforce anything, but to find what is right, necessary and sufficient under the conditions governing the case. Any structure, even the present floors, can be re-inforced by adding material, according to the simple rule that five is more than four and six is more than five.

In conclusion, I will state, that as far as I know, an engineer had never before to solve a problem of this character, under the peculiar circumstances I had to deal with in this case, and perhaps no one ever will again. Buildings covering under their roofs hundreds of acres, to be used for six months only, and then be doomed to destruction; buildings erected from one and a half to two years ahead of their use; an immense expenditure for a short temporary use of the buildings erected. That under such cir-

cumstances proper judgment ought to be exercised to combine the necessary strength, with the important factor of permissible economy, is evident, as well as the fact, that ordinary practice will not apply in this case. Whether I have properly judged in dealing with this problem, as I did, and which I tried to explain clearly and without bias in this paper, I leave to your discussion and to to the profession at large.

EXTRACT FROM REPORT OF TESTS, 1883.

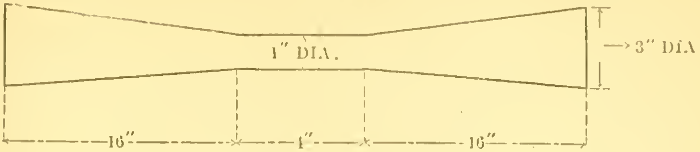
These specimens were taken from a tree 20.08″ diameter which had 51 heart rings and 19 sap rings. It grew in drift soil in Brookline, Mass.

Marks.	Direction of Loading.	Loads for Indentations of					
		.01 in.	.02 in.	.03 in.	.04 in.	.05 in.	.06 in.
le	 1.575 in. 1.575 in.	2100	2500	2670	2780	2860	2970
le	 1.575 in.	1410	2450	2960	3070	3190	3270

Marks.	Loads for Indentations of						Effect on Specimen
	.07 in.	.08 in.	.09 in.	.10 in.	.15 in.	.20 in.	
le	3020	3070	3150	3190	3500	3920	Sheared Fibres.
le	3330	3360	3390	3420	3800	3900	Sheared Fibres Split at end.

These specimens were indented perpendicular to the grain by a cast iron plunger, which covered the width of the specimen 1.575″ and 1.575, of the length, the indented section=2.48 sq. in.

REPORT OF MECHANICAL TESTS MADE AT WATERTOWN ARSENAL, MASS., OCT. 24, 1891, FOR A. GOTTLIEB & CO., CHICAGO, ILL.



Form of Specimens.

Test No.	Marks.	Diameter.	Sectional Area sq. in.	Tensile Strength Total lbs.	Tensile Strength Lbs. Per sq. in.
7919	No. 1 3x14	1.00	.785	6680	8510
7920	,, 2 3x14	.99	.770	4450	5780
7921	,, 3 3x12	1.00	.785	5340	6800
7922	,, 4 3x12	1.00	.785	6310	8040
7923	,, 5 3x14	.99	.770	6130	7960
7924	,, 6 3x14	.99	.770	5890	7650
7925	,, 7 3x12	1.00	.785	5910	7530
7926	,, 8 3x14	1.00	.785	4140	5270
7927	,, 9 6x6	1.00	.785	1830	2330
7928	,, 10 3x12	1.00	.785	554	710
7929	,, 11 6x18	1.00	.785	5580	7110
7930	,, 12 3x6	1.02	.817	7340	8980
7931	,, 13 3x14	1.02	.817	7895	9660
7932	,, 14 3x12	1.00	.785	4985	6350
7933	,, 15 3x14	1.01	.801	4790	5980
7934	,, 16 3x14	1.01	.801	6385	7970
7935	,, 17 3x14	1.01	.801	5670	7080
7936	,, 18 3x14	1.00	.785	4930	6280
7937	,, 19 3x14	1.01	.801	5580	6970
7938	,, 20 3x14	1.00	.785	7090	9030
7939	,, 21 3x14	1.01	.801	6610	8250
7940	,, 22 3x14	1.00	.785	7320	9320
7941	,, 23 3x14	1.01	.801	5980	7470
7942	,, 24 3x12	1.01	.801	5320	6640
7943	,, 25 3x14	1.01	.801	6015	7510
7944	,, 26 3x12	.99	.770	5230	6790
7945	,, 27 3x14	1.00	.785	5410	6890
7946	,, 28 3x14	1.02	.817	5990	7330
7947	,, 29 3x14	1.00	.785	6040	7690
7948	,, 30 3x12	1.00	.785	5490	6990
7949	,, 31 3x14	1.02	.817	8010	9800
7950	,, 32 3x14	.99	.770	3270	4250
7951	,, 33 3x14	1.01	.801	8180	10210

No. 9 was a defective specimen; cross grained.

No. 11, fractured obliquely.

No. 32 heated at centre when turned.

Correct: J. E. HOWARD.   A. L. VARNEY,
Capt. Ordnance Dept. U. S. A.
Commanding.

(Copy)

DISCUSSION.

MR. BENEZETTE WILLIAMS:—I would like to ask Mr. Gottlieb if he has made any estimate as to the difference in cost in the application of the factors as proposed by himself, and those adopted officially by the World's Columbian Exposition.

MR. A. GOTTLIEB:—I have not, but it is safe to say that in such large areas, say of 140 acres, that it is quite an amount. At the time I resigned the area was about 120 acres; it has been increased since, and if I remember right, the increase in cost for increasing the size of the timbers was something like $60,000; I have not figured it out.

I would also like to say to my fellow members that I have brought this paper up in good faith, expecting that everybody would have something to say about it and that a discussion would follow, and I would be glad to substantiate any thing I have said, and I desire everybody to come out with anything he would like to say.

MR. ROBT. I. SLOAN:—Has there ever been a contour map made of the formation of rock underneath Chicago?

MR. T. T. JOHNSTON:—I attempted to make such a map some three or four years ago, when I was connected with the City Engineer's office and succeeded in getting a general idea of what the rock under Chicago was. The data was taken from various sources, from the records of artesian wells bored and from certain surveys that were made in the city of Chicago. That map for some reason or other has been lost; it may be some where in the City Hall records, and I think that it contains all the data that could be had at that time. In that map the general contours in the township of Hyde Park were pretty well determined, and also in the City of Chicago. The ruling features in regard to the map were the appearance of the rock in the northern end of Hyde Park. where it seemed to come very near the surface, as also on the west side of the city, not far from the West Side pumping station; and on Chicago Avenue and Western Avenue, the rock seemed to come very close to the surface; on Fullerton Avenue, and under the present location of the river, at the South Branch and at the North Branch, the rock seemed to be deeper than any where else, as though there were valleys in the rock that had subsequently filled with clay. There was nothing to give a detail of the shape of the rock underneath the city. There was nothing brought out to show the general succession of the strata beneath the city, in the clay.

MR. C.T.PURDY:—I believe it would be possible to get records of borings from 50 to 70 feet in depth to the number of several hundred.

PRESIDENT COOLEY:—What is the general succession of strata down to the rock?

MR. PURDY:—It varies widely, but it is stiff and soft alternately; generally the surface clay, that which comes nearest to the top of the ground, is hard, harder than below, and yet under one of the buildings that is now

being built, one of my employees found that his weight was sufficient to push a shovel its entire length into the clay.

PRESIDENT COOLEY:—Is there any limit where settlement takes place? What is the usual allowance for settlement in these buildings; what is the usual weight on the foundations?

MR. PURDY:—The allowance varies somewhat in buildings, but generally from three to five inches are allowed for settlement. As a matter of fact, the loads which we are putting into the big buildings are less than those of many of the old buildings that have stood for years; there is no reason why the new buildings should not stand.

PRESIDENT COOLEY:—As Col. Burke is not here, I will tell a story and attribute it to him. I believe I can quote him as authority for the statement that there are six or eight places in the river where they have dredged down, and on coming back they found that the bottom of the river had come up. This is ascribed to the high buildings in the city exerting such a pressure that the soft strata are forced up. Col. Burke, superintendent of dredging in the city, said this to me, and I have had it stated to me by other people. I find the city benches out from one to three-tenths—they were supposed to be right when they were originally set. The general question arises on account of the city's being built to a certain extent on a substratum of soft clay Is that sub-stratum continuous over the site of the city and is it necessary or desirable to perforate through it by means of piles or cylinders with a view to reaching permanent strata? These are questions upon which I think all ought to express an opinion.

MR. C. L. OSTENFELDT:—Perhaps the experiment that has been made on a pile foundation under one of the high buildings in the city might be of interest. The piles used were fifty feet in length; driven down to a little above the city datum, and they were calculated to sustain a load of 25 tons each. Four of these were tested with a load of about 212,000 pounds. During the loading they settled one-half of an inch. A day after the total settlement was five-eighths of an inch; the load was left on for eleven days and no further settlement was noted.

MR. D. C. CREGIER:—I cannot give you anything very interesting touching the foundations of the City and County buildings, more than to say that the county side of the public edifice was thoroughly piled. I don't know how many piles were put under, I presume some gentleman here knows. I am reminded by Mr. Gottlieb of the fact that they were put so thick that when they drove one down where they wanted it, the next one that was driven down drove up the first one, and they had to keep driving right along; they were a good many months at it. I want to add, Mr. President, that the city building had no piles. I want to add also, for whatever it is worth, that the foundation was uniform, and it will occur to the gentlemen here that the weight is not uniform; when we came to put in the floors it had settled in some portions seven inches and a quarter. I am informed that the county side—I do not know the figures, settled still more notwithstanding all the piles. Now, Mr. President, while I am up, it may be interesting to state, we built the water tower on the North Side in '67, a very heavy structure. The specifications of the architect requir-

ed piles to be driven until they entered the clay. I was present daily, and witnessed the driving. The sand at that point is about 17 feet—pure lakeshore drift sand. Piles were driven with a very heavy hammer, necessarily, in order to comply with the letter of the specifications, until they would go only a quarter of an inch by actual measurement and the hammer would rebound two or three times. But the specifications must be complied with, wherefore the piles were hammered and hammered, rings were put on to save the pile, and by and by the sand was passed the pile entering the clay, and then the pile went down 11 inches, and it occurred to my mind that they had reached the maximum of density before they got to the clay.

Mr. Gottlieb:—In regard to driving piles to clay or hard-pan, I have in my paper referred only briefly to the fact that in Jackson Park we drove some piles and loaded them with sand in order to test what the piles will do. We had in one place four piles driven together and a large wooden box built on top loaded with sand; we had about 40 tons of sand in that box, so that there were 10 tons on each pile. These piles were driven purposely to different depths; one was driven to hard-pan, the next one to the clay the next one was left higher up, to ascertain if they would settle differently under that load, but we noticed no difference in the settlement. The explanation I think would be that the side friction of the sand holds up the pile; if that pile is driven by a hammer, the friction of the sand upholds it. If you get through that sand and penetrate to soft clay there may be a chance for the sand to run down into the soft clay. I think it is better, if you cannot reach hard-pan, to stay in the sand.

Mr. Geo. C. Prussing:—I did not know that in this assemblage anything would be in order from an unprofessional. My general experience has been that the broader base, or rather the floating foundation is entirely the best on our soil. All the pile foundations I have seen, and I have made it my business to see a great many, have been measurably a failure, and to-day I am a very strong advocate of the broader base or the floating foundation, the spread foundation, apportioning width of the base to the pounds to be supported. I would like to say about the Custom House, that our soil is not strong enough to stand the folly there displayed. Some portions of the building are extraordinarily heavy, heavier perhaps than any one in the room would think possible to pile up; others are unproportionally light, and, as has been stated here, the foundation, the artificial foundation, consists in a continuous sheet of concrete made in different layers but altogether three feet six inches thick. Borings showed an old slough at the Adams street corner running some distance into that block. The wise men from Washington determined that if they got plenty of concrete on top, if they got it three feet six inches thick, that slough didn't matter, as the concrete would be amply sufficient for anything that might be put on top. They proceeded on that theory and it has resulted in failure. I do not know that I have anything more to add.

Mr. C. T. Purdy:—During the years that I have been in Chicago this question has been my constant study. I believe as Mr. Prussing does,

that the spread foundation as he terms it proportioned to the loads is the better one.

If we could drive piles to bear upon a real hard pan or solid rock, we could put a greater load per square foot over the area covered, than we can with the spread foundation and the limits of our already high buildings would be increased. Some claim that this can be done, but its practicability has yet to be demonstrated.

I have been interested professionally in the construction of some ten or twelve of our largest office buildings using the spread foundations. They all settle, but that does no harm; the trouble comes when they settle unevenly.

When we calculate the loads in a building, we include everything used in the construction, and exercise the utmost care to determine which foundation carries each portion. In determining the weight of the floor, the tile arch, plastering, concrete, iron-wood and marble tile are each determined separately, and all other parts are treated with the same care.

We believe that the secret of equal settlement is very largely in the proper distribution of these loads. When they are determined we proportion the columns to them and the area of clay covered by each foundation. In these very high buildings, fourteen and sixteen stories, with foundations made in this way we have had less settlement—a great deal less—than has been spoken of here to-night in these older stone buildings, and I have yet to learn of a case where reasonable care was exercised to secure the proper proportions that settled unevenly enough to reveal the fact in the construction.

Referring to the relative loads carried by the old and the new buildings, I might add that when they tore out the old foundation in the Gossage building a year ago they found the clay loaded two tons or more per square foot; while the allowance on the clay in the Fair building, which is to be seventeen stories high, is only 2,900 pounds per square foot.

It is a well established point that to drive piles through a hard area, letting them just break through into a soft medium, is bad engineering. It has been my experience that the strata varies greatly, and I think the borings that have been made by different engineers in the city will bear me out in that statement. Quite a large number of borings have been made under the Leiter building, General Sooy Smith has made a great many in different portions of the city, and it seems to me there is no line of work that can be of more real benefit to the Society and the engineering profession at large than the compiling of data on this subject. I think too that there is another point in reference to driving piles that is important and that is the shaking of the surrounding buildings. That must be very important. Our buildings settle perhaps an inch when the iron frame is up, the brick work on, and the arches in, and another inch of settlement comes, as near as I have been able to get at it, when the plastering is put on. After the building is completed and occupied there is no more settlement worth mentioning so far as we have been able to determine.

Mr. H. B. Herr:—We have pounded down a good many piles for

foundation work and other purposes, and I think that Mr. Purdy's views are very much in accord with the experience that I have had in pile work. I am well satisfied that if you drive a pile until it reaches the hard clay anywhere in this city, that is the best you can do for foundation support, and I believe it can be done anywhere in the city. There is no difficulty in driving a pile to any depth necessary to reach the clay; it is everywhere under the city and at not very great depth perhaps anywhere. Under the depot at Harrison street, once the Wisconsin Central, now I believe called the Northern Pacific, there were quite a number of piles driven, some 1,500; they were driven entirely according to the weight they were to sustain. Under the tower, for instance, in the corner, there were a great many driven; if I remember they were 3½ feet centers and a large number of them were driven to reach the clay, the hard clay. They were fifty feet long and the butts were driven to probably a foot or two above city datum. Now in driving those piles, close as they were driven, and butts 18 inches, many of them, none came up while an adjoining one was being driven down, they were down so deep that the friction was too great to allow of their coming up, but the clay came up and we kept shoveling that away as it came; the clay came up but the piles stayed down, so these in the County Building mentioned would have stayed down if they had ever been down properly. But they never got as deep as they should have been; they were small and perhaps short piles, and when one was driven down, the other would come up quicker than the clay would perhaps. Piling is sure if it is properly done, and the depth of the piles simply depends on the depth of the clay, that is all. There is a point that Mr. Gottlieb spoke of in connection with the pile work that I would like to ask a question about. I understood Mr. Gottlieb to say that in the tests that were made with the four piles, the one that was driven in the sand was driven and not jetted down and that that was the reason it did not settle; I am wondering whether you got that from actual experience.

Mr. Gottlieb:—I have not. The only thing I thought of is in jetting down, it takes some time before the sand hardens again around the pile.

Mr. Herr:—That is a subject that is discussed a great deal, perhaps not so much of interest to engineers as to contractors and men for whom they build. The question is whether a pile put down by the jet will offer as great a resistance to a vertical pressure as one driven in the sand. Before I had any experience in actually placing the piles in the sand, I thought it must be that the pile that was forced in there, blow after blow, must stand more pressure than one that was put into the hole and held there until the sand hardened around it, but I saw such results in work of that kind, in piles being jetted down, that I began to theorize on it to see whether I could get a theory to suit what seemed to be the practice, because I am quite confident from my experience, although it has never been tested as it ought to be, that the pile that is jetted in the sand will resist fully as much vertical pressure as one which is driven. There is always a reason for everything. and it seems to me there is a reason for that. You drive a pile in the sand; it has bark on it, most invariably. In driv-

ing a pile into sand or any other material, all the cavities in the bark, or any unevenness, even a little bend in the pile, probably, will be filled with a compressed mass of material. That remains there as it goes down, and becomes a part of the pile; it is transported from where it was originally along with the pile and that pile goes with this addition as part of it. In the other case, when you jet a pile down, what is the result? Then it is put down into quicksand, whether it was a quicksand before or not it makes no difference, it is a quicksand, a mixture of water and sand, which is a quicksand. While that pile remains in that hole, you have got to hold it, but this quicksand soon gets into every little cavity there is, and the material that is around it is not a part of the pile at all, it is a part of the earth, and you have got to break something, you have got to break through that sand, whereas in the other case, there is nothing to break; there is a distinct line of demarkation between the material on the pile and the material in its old place. Now I think that that probably accounts for the fact, which I am not sure is the fact, that the pile put down with the jet will resist more pressure than the one driven. If any one knows of any experiments on that matter, I would like to hear of it.

Mr. Benezette Williams:—I think there may be some other reason for piles put down with the jet holding even more firmly than those that are driven, and that is that the sand that has been put through the operation of washing settles into closer relations, one particle with another, than it had previously—it becomes more compact. But I wish to say a word in regard to the clay underlying the city, especially with reference to what Mr. Purdy has said. The experience in driving tunnels through Chicago soil is that on the given level and substantially the same distance from the rock and the same distance from the surface, you will pass from a very soft clay into which you can run your finger, to clay of entirely different character; the clay lies in irregular masses, in pockets, alternating hard and soft; nothing systematic about it; any building that is founded here is founded on just such material. It is not homogeneous or uniform or in horizontal layers, and it is a wonder that these buildings stand as well as they do to-day. It matters not how carefully the weight of the building is calculated and the exact relations which it sustains to the foundation, one part of the foundation will be on a hard material, and another on the soft material, so that even with all careful calculations I should not be surprised that the building should settle some.

Mr. A. Gottlieb:—I would like to suggest one point with reference to all this foundation business; we are told and we know that at a certain depth under the city there is a very soft clay, in certain layers we find quicksand the layers are not regular of course, sometimes the clay reaches further down, sometimes higher up, but the soft clay is met at some strata. The question to my mind is this: What difference does it make to foundations whether you have that strata of clay 10 or 20 feet thick, so long as that clay cannot leave its place where it is? It is confined, cannot get out. What difference does it make whether on top of that is five or ten feet of other material? I do not say that it makes no difference, but I ask, what difference does it make, as long as the underlying strata is

wedged in and cannot escape? If water is wedged in and cannot escape, it will bear just as well as a rock; why can't you place buildings on top of material overlaying that soft clay if it cannot escape.

MR. D. C. CREGIER:—A question has suggested itself to me whether we are not behind in the new era of building? Whether it is not a sort of go-as-you-please system of building? I have listened to the remarks of the gentleman who calculates the weight of the building he puts up very carefully, even to the wainscoting, marble floors and all like attachments to the building. Looking at that photograph of the 20 story building—somebody has calculated it as an office building. Revolutions may come and it may be loaded from top to bottom with printing presses, reams of paper, etc. You calculate that for an office building and make allowances only for the contents of a building to be used for such purpose. Is it not the duty of the public authorities to ascertain not only if the walls shall be so thick and so many stories high, but whether they should not ask what the building is to be used for, whether for hardware or furniture. I think that the subject before this Society to-night is a very interesting one, and I think if we knew more about the foundations of Chicago or rather the ground of Chicago, that we should be apt to get up buildings that would not be running around the streets. Some of you will recognize the fitness of the expression. Where the Chamber of Commerce is built there is a very peculiar condition of soil. My own experience bids me say what is pretty well known, that where the crib stands in the lake, the clay crops out at the bottom of the lake there; as it goes westward or shoreward it runs out, but there are 17 feet of sand on top of it, and the clay commences to rise gradually and at about Larabee street it crops out to the surface and it stays clay pretty well west of that. At Fourteenth street and at Twenty-second street, on the river, it looks as if it were laid there in layers purposely so that the foundation would slip. At the Twenty-second street pumping works, the rock is 42 feet from the surface. I speak of that because the stratification has been inquired about.

MR. ROBT. I. SLOAN:—Whether this strata of clay is hard and stiff, or whether it is soft, I think the difference is great. Until the strata of clay is hard, homogeneous, you are building on a beam, otherwise not.

MR. A. GOTTLIEB:—I think you misunderstood my question. I said what difference does it make whether the soft clay is near the surface or further away from the surface.

PRESIDENT COOLEY:—A newspaper made Gen. FitzSimons say the other day, that clay was likely to come up several blocks away. It was mentioned to me the other day that some piles were put down by the C. B. & Q. Road, I do not know whether in the city or not, in the shape of wooden cylinders. Does any one know anything about the wooden cylinders, put down by dredging out the inside. I understood they were 6 feet in diameter, and made of 12×12 timber. The interior was filled with concrete.

MR. HENRY GOLDMARK:—In regard to cylinders for piers of buildings, they have been used in Kansas City within the last two years under the City Hall. The building stands on what was once a ravine with a rock found-

ation, but in the course of years it has been pretty nearly filled up with ashes, material and street dumpings, entirely unfit for foundations. The expense of carrying down walls would have been very considerable, so that the superintendent hit upon the scheme of sinking iron cylinders. I think one-quarter inch boiler plate and four to five feet diameter, through those dumpings down to the rock, filling the cylinders with concrete after they were excavated and building the walls of the building on this substructure, usually putting iron beams or steel beams from one of these cylinders to another. Thus a foundation is secured that seems to be very satisfactory, and in that case was very much more economical than anything else that was suggested. A well sunk at Memphis, Tenn., in connection with the water works there is 30 feet in diameter and I should say 60 feet deep. It was sunk by undermining the ring and building brick work on it. It is not very expensive and it is an exceedingly compact arrangement.

MR. T. T. JOHNSTON:—With regard to the time required in the hardening of cement, I bought some Louisville cement for a brick wall that was at the bottom of shaft, and it didn't harden as fast as I wanted it to; there was a period for two or three months that I could pick it off with my fingers, but at the end of six or eight months it became quite hard.

MR. C. T. PURDY:—In putting in the foundations of the Womans Temple Building, they had to take out an old foundation under which and over the entire area of the building was a layer of concrete 12″ thick. I do not know what cement was used, but the concrete could not have been better. In one case the new foundation encroached on the old foundation under the party wall a few inches. This was made of iron beams bedded in concrete and both the ends of the beams and the concrete had to be cut away. The workmen reported that they found as much trouble in cutting out the concrete as they did the iron, which could not have been the case, if the concrete had not been remarkably hard.

I might add that the iron was found to be well preserved.

BY T. G. GRIBBLE, A. M. I. C. E.

The balance of opinion appears from the discussion to be in favor of a "spread foundation." It would seem to have been a difficulty with some of the larger buildings to obtain anything like an even distribution of pressure. Any application of load upon an extended horizontal surface cannot produce an even pressure although the material itself were perfectly homogeneous, much less is it possible to obtain an even pressure upon a heterogeneous foundation such as Chicago subsoil. In the construction of heavy walls such as those of reservoirs upon a rock bottom, the pressure varies from a maximum under the center of gravity to a mimimum at the outer edges. In the elaborate experiments made at Berlin upon the supporting power of sand when constructing the City Railway, it was found that to widen the footings of the test piers beyond an angle of 60° did not increase the supporting power because the base rounded causing the edges to break off; the pressure not being uniform. To spread a thick, horizontal layer of concrete over the whole area of a building would appear to be

a heavy outlay in return for a comparatively small return in supporting power. There does not appear to be any record of the application of the brick or concrete inverted arch to the spread foundations of Chicago and yet this would seem to be the most natural means of obtaining a uniform pressure. Supposing for instance two walls twenty feet apart, to stand upon a bed of concrete 3 feet thick laid horizontally. The soil to be compressible within safe limits up to a pressure of three tons per square foot or to be incompressible up to a pressure of one ton per square foot. It is evident 'that the concrete midway between the walls would be of no assistance in supporting their weight because if we imagine the layer of concrete acting as a beam between those supports, it would break under its own weight. If made to form a mattress with railroad iron, as in recent foundations, the distribution of pressure could be calculated as for reservoir walls but with nothing but concrete, it is probable that lines drawn at an angle of 60° from the outer and inner faces of the wall to the bottom of the concrete would include all the area of resistance which the material was able to furnish. If the wall were two feet thick, these lines would include a surface of 5½ feet and represent a supporting power per lineal foot of wall, for the two limits of pressure, of 5½ tons and 16½ tons respectively.

If the walls stood upon a smooth bottomed inverted arch, the pressure would be at a maximum at its crown and would more nearly approach uniformity the flatter the arch, but with of course, increase of stress. If the bottom of the arch were stepped in short horizontal steps, the pressure would be still more nearly uniform and might be assumed to be evenly distributed. The safe limits would then be 10 and 30 tons respectively. The resistance of the arch to crushing at the crown would be greatly in excess of these amounts. It would appear from these rough figures that double the resistance to vertical pressure might be obtained in this manner but it would also possess the advantage of distributing unequal pressures because a lighter wall at one end of the invert could be made to resist a heavier pressure at the other end by trussing the cross walls and partitions.

About twenty years ago the writer assisted at the construction of the Govan graving dock for the trustees of the Clyde navigation. The side walls were built in moving sand and stood upon a brick invert five feet thick and about 90 feet span. The sand was not confined in any way but there was no perceptible settlement during construction. After the dock was built, it was determined to build another one along side of it and to pump from the one station by means of a culvert. To lay this culvert it was necessary to excavate down to the bottom of the existing walls with a 12 inch centrifugal pump kept going all the time. In spite of this apparently risky proceeding no settlement occurred in the wall, demonstrating the efficacy of the invert in distributing the pressure of the walls over a large area.

It is suggested that the same principle might have a wide application to the heavy buildings of this city and the bottom of the invert might be utilized for storage purposes.

By Onward Bates.

Commercial white pine timber is one of the commonest of the materials of construction in this locality, and the stresses which shall be allowed in its use are of the first importance to the builder and the investor.

Mr. Gottlieb has done me the honor to quote in his paper from one which I presented to the American Society of Civil Engineers on a similar subject. Allowable stress is a matter of opinion, and the opinions of those who have the opportunity of observing the service of material under stress should have weight in determining what may be considered by the profession as proper allowable stress. My opportunities for studying the working strength of white pine under transverse stress have been exceptionally great, and I can write on the subject with confidence, always, however, subject to correction if I am shown to be wrong in my conclusions. I hoped for a discussion on my paper on "Pine Stringers and Floorbeams for Bridges" which would have brought out the opinions of Engineers on the allowable fibre stress for them, and I am now pleased that Mr. Gottlieb's paper gives me the opportunity of adding my mite on the subject. My investigation was not of the strength of pine timber in itself, but of the stringers and floorbeams as used in bridges. There was no selection of a particular class or condition of timber, the object being to ascertain first, the strength of the timber at any time while in service, and second, to determine what stress should be allowed upon it.

Quoting Mr. Gottlieb:– "While Mr. Bates acknowledges by his first conclusion that green timber is not as strong as after it has been seasoned, the results of his tests do not warrant such a statement if he considers the twenty-six old pieces as equivalent to seasoned timber." I think he has drawn a wrong conclusion from the tests, for the smaller results obtained from the old stringers were due to their being season cracked, which was not the case with the new stringers, and my 4th conclusion which he quotes states that "while age does not weaken the timber itself, it weakens it by season-cracking."

The results of this series of tests are lower than any which I have seen reported, and careful study of all stringers cracked in service which I have had occasion to note, leads me to the opinion that no tests of small dimensioned specimens of timber will give a safe figure for the ultimate strength of full sized stringers and floorbeams during their period of service. My own practice is to assume a modulus of rupture of 4000 pounds per square inch, and to use a factor of safety varying from 4 to 2 according to my judgment of the conditions to be provided for. The conditions of the use of timber in the Exposition buildings are different from those in bridges. In the former, the timber is housed in and protected from sunshine and rain and not so liable to the objectionable season-cracks, it has the opportunity to season under favorable conditions for perhaps a year before it is subjected to its full working load, at which time it should be at its best, and in the six months use of the building it will not have time to deteriorate. Under the circumstances I consider Mr. Gottlieb's allowance for "tension in extreme fibre in caps and joists, 1500 pounds

per square inch," to be entirely reasonable, and that the adoption of any less unit stress would be wasteful. In support of this statement I will show the practice of the principal railroads of the Northwest with the stringers in their trestle bridges.

The three factors are: first, the loads; second, the dimensions of stringers; and third, the resultant stresses. Referring to the Keystone Bridge Company's specifications for Railway Bridges dated 1887, there is a table of equivalent uniform loads per foot of track calculated from engine wheel loads, from which I take the following:—

Span in feet.	Engines.				
	86 tons.	87.92 tons.	90.5 tons.	92.3 tons.	101 tons.
12	6000	6160	6920	6630	6670
14	5880	6030	6700	6480	6740
15	5760	5910	6540	6350	6670
16	5630	5780	6360	6190	6560
20	5400	5190	5960	4840	6190

I assume the 90.5 ton engine, which is a Penn. R. R. class R. engine, for calculating the stresses on stringers, believing that each of the roads which I will consider have engines which will bring as heavy or heavier loads on short spans. In calculating the resultant stresses I will add nothing for impact. Professor Weyrauch's law "that a rapidly applied load, quickly removed, has double the effect of a static load" does not in my opinion apply to the stringers of trestle bridges where the mass of rails, crossties and stringers present a great amount of inertia to be overcome. Besides this, the line of impact is parallel to the span and is not directed against it. This is a heretical opinion, contrary to all the scientific bridge specifications, but it is a well known fact among bridge carpenters that if a short span is weak it is safer to go over it at at a fast speed than at a slow one. Those who like may get any fibre stress they choose by adding to my results a corresponding percentage for impact.

The dimensions of the stringers hereinafter mentioned were, with one exception, furnished to me by Chief Engineers in February 1890. The exception I obtained by measurement. In the calculations, I take as stated the uniform load corresponding to the 90.5 ton engine, with an effective span 6 inches less than the nominal length, which is the distance between centers of bents. Where there are side stringers I assume them to carry the total dead load and the track stringers to carry the total live load, and when there are no side stringers, the track stringers to carry the whole. Where stringers are continuous over two spans and break joints

I have made no allowance for their continuity in resisting vertical loads. I give the practice of different roads by numbers, and the calculated stress in extreme fibres of stringers in accordance with the foregoing assumptions:

1st. Span length 15′ 9″.
6 track stringers, each 8″ × 16″ × 15′ 9″.
2 side stringers, each 6″ × 16″ × 15′ 9″.
Fiber stress 1,083 pounds per square inch.

2nd. Span length 15′ 9″.
6 track stringers, each 6″ × 16″ × 16′ 9″.
2 side stringers, each 6″ × 16″ × 15′ 9″.
Fiber stress 1,444 pounds per square inch.

3rd. Span length 16′ 0″.
6 track stringers, each 6″ × 16″ × 16′ 0″.
2 side stringers, each 6″ × 16″ × 6′0″.
Fiber stress 1,492 pounds per square inch.

4th. Span length 16′ 0″.
4 track stringers, each 10″ × 16″ × 16′.
No side stringers.
Fiber stress 1,405 pounds per square inch.

5th. Span length 16′ 0″.
4 track stringers, each 8″ × 16″ × 32′ 0″.
2 side stringers, each 8″ × 16″ × 32′ 0″.
Fiber stress 1,678 pounds per square inch.

6th. Span length 15′ 0″.
4 track stringers, each 8″ × 16″ × 30′ 0″.
No side stringers.
Fiber stress 1,575 pounds per square inch.

7th. Span length 15′ 0″.
4 track stringers, eadh 9″ × 16″ × 30′ 0″.
2 side stringers, each 9″ × 16″ × 30′ 0″.
Fiber stress 1,343 pounds per square inch.

8th. Span length 14′ 0″.
4 track stringers, each 8″ × 16″ × —
2 side stringers, each 6″ × 16″ × —
Fiber stress 1,341 pounds per square inch.

9th. Span length 12′ 0″.
4 track stringers, each 7″ × 14″ × 24′ 0″.
2 side stringers, each 7″ × 14″ × 24′ 0″.
Fiber stress 1,501 pounds per square inch.

10th. Span length 20′ 0″.
6 track stringers, each 8″ × 16″ × 20′ 0″.
No side stringers.
Fiber stress 1,743 pounds per square inch.

Whether these ten examples show good or bad practice, it is a fact that it is an accepted and successful practice over hundreds of miles of

pile and trestle bridges on the great railways of the Northwest. If experience is worth anything these figures will speak for themselves, and if their accuracy is questioned they may be verified by anyone willing to take the trouble of investigation.

Regarding the question whether such material as is specified in Mr. Gottlieb's paper, "could be obtained in such large quantities, as the immense buildings will require, and considering the time in which it will have to be furnished", the best answer to it is that the Railway Companies are able to obtain timber for their bridge demands with fully as exacting specifications.

Concerning the unit strain "for bearing of vertical posts upon underlying blocking (head or end of fiber upon transverse fiber) 600 pounds per square inch." I am not able to cite a precedent for this pressure. I have no doubt that this pressure is exceeded in the bearing of iron on transverse fiber of white pine in a great many existing Howe truss railway bridges, but I am not able at this time to name a particular instance. Mr. Charles Davis Jameson, C. E., has published a series of articles on Howe truss bridges in the Railroad and Engineering Journal, and on inspection of his published plans, I find his plate washers are in some cases proportioned to give a pressure of 700 pounds per square inch on chords of yellow pine. In the standard plans of Howe truss bridges of the Chicago, Milwaukee & St. Paul Railway the pressure of plate washers on chords of white pine is limited to 350 pounds per square inch. In this case the timber is exposed to the weather and is supposed to last from 8 to 10 years, in which time it may be softened by moisture or decay, and it is also subjected to the vibrations of passing trains. For the bearing of vertical posts on blocking in a building which is to be removed after two or three years, a pressure of 600 pounds per square inch is not in my opinion excessive.

The question of allowable stresses for timber is largely one of judgment based on experience, and on the points covered in this discussion I have offered my opinions, leaving it to the Society to form its own estimate of their value.

Mr. A. Gottlieb:—I would like to say a few words with reference to the paper of Mr. Bates. In the first place I am very glad that Mr. Bates took the matter up and discussed it in the way he did very fully, and I am very glad that he had new data for his paper in the American Society of Civil Engineers proceedings. I know that his data are very valuable, because they come from experience. I touched upon the subject of Mr. Bates' paper in my own paper for a very good reason. It shows the latest data from the latest experience on that subject. Outside of Prof. Lanza's, experiments I do not know of any that have been made on such large scale as Mr. Bates gives. Why I divide the results of the new timber from the old is this: Mr. Bates in his tests for his purpose was entirely correct to do as he did, to show what the new stringers, and what the old stringers would be worth, whether they had been weakened by use and exposure or not; but I regret one thing, and that is this, that Mr. Bates in his paper before the Society, himself did not separate the results, in determining the average modulus of rupture and of elasticity, that he did not divide

the new stringers from the old ones, and I will give him the reason. In bringing a paper like that before a professional Society, before members who know the subject, you do not need to be as careful in stating how you arrive at this and at that conclusion, as if you go before bodies who do not know anything about it. Engineers know what Mr. Bates means by that, while others do not, and anyway in the shape that it is now, drawing averages from old and new stringers together, it is misleading, and in fact it was presented to me in order to change my mind from what I had determined would be the proper strain for the structures—it was presented to me to show that Mr. Bates paper states so and so. Well, I could not go into the details then as I went into my paper, and that is the reason why I pointed out particularly, that wherever the results should be used as guides for future construction, there ought to be discrimination made between new material and old. As to what Mr. Bates says, that old timbers did not stand as much strain because they were season cracked, I admit that they stood less than the new ones on account of season cracking, which was aggravated by exposure. Those matters are all very well in the way he means, but they are misleading to those who do not understand the matter properly.

Mr. O. Chanute:—I believe that there will be but little difference in opinion among engineers as to the fact that, whether the timber was new or whether it was season cracked, the dimensions and strains proposed by Mr. Gottlieb were abundantly safe. He has made in his paper, as I understand it, two points, the one as to the safety of placing a strain of 600 pounds on the square inch upon the end grain of timber in posts, and the second as to allowing a fiber strain of 1500 pounds to the square inch on floor joists and beams. I take it that it is within the experience of all of us that such strains, and even greater strains, are in daily use in our warehouses and have proved abundantly safe, whether the timber is new or whether it be old. The fact is I think that those strains are greatly exceeded in many cases. I imagine that an inspection of the size of posts under water tanks would show that they are strained with 1000 or 1200 pounds to the square inch, and that an inspection of the floor joists of many railroad warehouses would show that with a full load they are strained to over 1500 pounds to the square inch, and as Mr. Bates has stated it, more than a sufficiency is liable to be considered as wasteful, particularly when operating on such very large areas and exposed to such possible dangers from fire. In connection with the latter I would like to ask Mr. Gottlieb whether it was contemplated at any time in constructing those World's Fair buildings, to adopt the slow burning construction which has been so largely used in Eastern manufacturing mills. That construction, as I understand it, consists in substituting for the ordinary floor joists, which are generally 2×12 or 3×12 and spaced 12 to 15 inches between centers, stringers 10×12 or 12×14 which are spaced 8 to 10 feet apart, on which is laid a flooring of 2 inch planks, which is again overlaid by another 2 inch course of plank, the result being that instead of having horizontal flues through which a fire burns with great rapidity when it gets among small joists, large beams and tight floors are substituted, in which the fire is at

once checked and prevented from spreading, and easily put out.

Mr. A. Gottlieb:—In reply to Mr. Chanute's question I will say this: I do not think I can speak authoritatively in this matter. I have had charge of the engineering work and another department has had charge of the architectural work. Naturally this question suggested by Mr. Chanute is in the architect's hands. So far as the floors are concerned, they are not fireproof as Mr. Chanute explains. They were simply joists resting on top of wooden caps. I know that the intention was to firepoof the outside of the frame buildings by covering them with staff, as it is called, a composition mostly of cement, and as a binder some vegetable fiber like burlaps, and the whole mass united by a solution of glue, forming a very tough, elastic and plastic material, which can be formed very easily in any desired shape and made in any number by simply molding them like castings, and I think the outside of the buildings will be as thoroughly fireproof as possible. The interior was not intended to be fire-proofed with staff. Some experiments were since made, I understand, with some fireproof paint which gave satisfactory results, but from my own knowledge I cannot say more about it.

Mr. J. F. Wallace:—I listened to Mr. Gottlieb's paper at our last meeting with great interest, and I have since examined the printed report, and I wish to say that I consider his position in regard to unit strains as safe and conservative.

In reference to the point mentioned by Mr. Bates in regard to impact, at one time I made a few experiments in this line that may be of interest to the Society. At the Sibley bridge we had two 175 foot spans, the trusses of which were about 14 foot centers. The floor system consisted of long ties, 6×14 inches, that rested edgewise upon the top of these trusses, upon which were the ordinary guard rails, etc. To test these ties the Santa Fe Company furnished us with one of its heaviest engines. In testing the deflection of the ties, we drove a nail into the tie, letting the point slightly protrude and sharpening it with a file, then placed a pine board, smoothly dressed, parallel with the tie, so that when the engine passed over the track, the deflection of the center of the tie would be indicated by the scratch of the nail upon the pine board.

We ran the engine over these ties that were tested at about a speed of 30 miles an hour and afterwards ran the engine slowly on the same ties and permitted it to stand there for the space of four or five minutes. The deflection under the high speed showed about one-eighth of an inch less than the deflection with the engine standing over the same ties.

In testing the 400 foot through truss spans we ran the engine over the spans at about 35 miles an hour and took the deflection on the center of the span and also took the deflection of the span after the engine had moved on and come to a standstill. The deflection under the high speed was slightly less than that under the low.

President Cooley:—Every small boy can tell you that by going over thin ice rapidly it is less liable to break. At the same time a very interesting point for record is made by Mr. Wallace in regard to the deflection produced by rapidly moving trains on smooth tracks.

MR. J. F. WALLACE:—I neglected to mention another experience we had at Sibley. We desired to have the engine run at a speed of from 20 to 30 miles an hour and then brought to a stand still as suddenly as possible, that is, to have the engineer make what is called an "emergency stop." It required repeated trials before the engineer had enough confidence to stop his engine as suddenly as desired. Finally, however, he was able to stop his engine inside of 100 feet, by dropping sand on the rails, reversing his engine and applying air. The deflection under the shock was slightly less than tnat under the engine remaining at rest.

MR. A. GOTTLIEB:—There is a natural law for all those things. If you load a beam with a certain load and leave that load on for a long time there is a deflection; if you take the same load and leave it there only a half or quarter of an hour there will be less deflection, and particularly so in wood. Now in running very fast over a short span the inertia of the material is counteracting the action of the load and the beam has hardly time to deflect. Everything takes a certain time: it takes a certain time to strain every part from the top to the bottom, so that if the train is moving very rapidly over the bridge the time is not very long before the strain is relieved; before each part of each member had time to respond, but there is a certain speed where the momentum will fully come into play.

MR. HORACE E. HORTON:—I would like to add my testimony to the effect that the strains used as stated by Mr. Gottlieb in his paper are abundantly safe. There is no question whatever, as any one with experience in timber will know.

MR. BENEZETTE WILLIAMS:—I would like to ask Mr. Gottlieb if we are to infer from his last remark that some intermediate rate of speed between the very rapid movement of the train and no movement at all, will produce the greatest deflection?

That is whether the maximum deflection comes during a moderate movement.

MR. A. GOTTLIEB:—I cannot say exactly the maximum deflection, but it is natural to presume that rapidly moving trains will have, a certain bending effect by producing a momentum. The more imperfect the road bed and the rolling stock are the greater will be the momentum.

MR. HENRY S. MADDOCK:—Does not the running of a train at a rapid speed tend to shorten the life of a structure more than that at a slow speed?

MR. J. F. WALLACE:—I think that high speed is more injurious than the low speed, although it may not be indicated by the immediate deflection of the material, and that it brings an unusual strain upon particular parts, and does not give an opportunity for the different members to have the strains applied to them, in the way in which it is calculated that they should be.

This whole question of impact, however, due to speed is one upon which engineers have little, if any, reliable data and certainly there is a wide field for investigation.

PRESIDENT COOLEY:—I would like to hear from Mr. Chanute something in regard to the slow-burning construction of which he spoke. Is not the wholesale house of Marshall Field & Co. on Fifth avenue built on that plan?

MR. CHANUTE:—I do not know that. I know that the plan was brought to the attention of the Exposition people by Mr. Edward Atkinson when they began planning for the buildings. Mr. Atkinson has probably had more experience in that construction than any other living man, and he has accomplished some very remarkable results in diminishing the insurance and fire risks in the mills and factories of New England. Little by little, by the process of evolution, a method of building has been worked out which is a great deal cheaper than iron and almost as safe, so that I understand the insurance rates on mills in this country to be as low as those in England, which latter are said to be thoroughly fire-proof; that is fire-proof so far as the material of which they are constructed is concerned, but not with regard to their contents. Mr. Atkinson I believe took some pains at the inception of the Exposition here to call attention to that method of construction and to urge its adoption for these buildings. It is very little more expensive than the methods which have been adopted. It simply concentrates the joists instead of scattering them and spacing them about 15 inches apart, and it certainly would have diminished the risk greatly. Moreover the cost of these buildings, as it is, will be almost as high as that of the buildings in Paris, which were of iron, while these are of wood. The Palace of "Miscellaneous Industries" in Paris cost, if I remember right, 84 cents a square foot, while the "Manufacturers' Building" here is estimated to cost 75 cents per square foot, or very nearly as much; and I believe it would have been possible, by reducing the spans, to have constructed the building of iron for the same price that it is now about to cost in wood. The spans in Paris were 82 feet, and by making the spans 50 feet I believe it would have been possible to build in iron nearly as cheap as now in wood.

MR. BENEZETTE WILLIAMS:—I want to say that the Marshall Field Building about which the President inquired, is constructed on that principle as is also the Walker Building at the corner of Market and Adams street. The principle of slow burning construction simply concentrates the timbers and exposes them entirely on both sides. Mr. Atkinson published, I should think two years ago, an interesting article on that subject in the *Century*. It was a very valuable article.

MR. H. L. BRIDGMAN:—Mr. Atkinson has published a number of instructive papers on the subject, of great interest, which he furnishes to interested applicants. I have found, however, in my practice of constructing smelting works, that white-wash is one of the best fire-proofings we can get. A coat of white-wash will prevent the spread of fire as effectually as any thing.

A NEW METHOD OF CALCULATING AREAS IN LAND SURVEYING.

BY CHAS. S. HOWE, PH. D., MEMBER CIVIL ENGINEER'S CLUB OF CLEVELAND.

[Read October 13, 1891.]

Let $O\ A\ B\ C\ D$ be a field whose area is to be calculated. Divide the field into triangles by the lines $O\ B$ and $O\ C$.

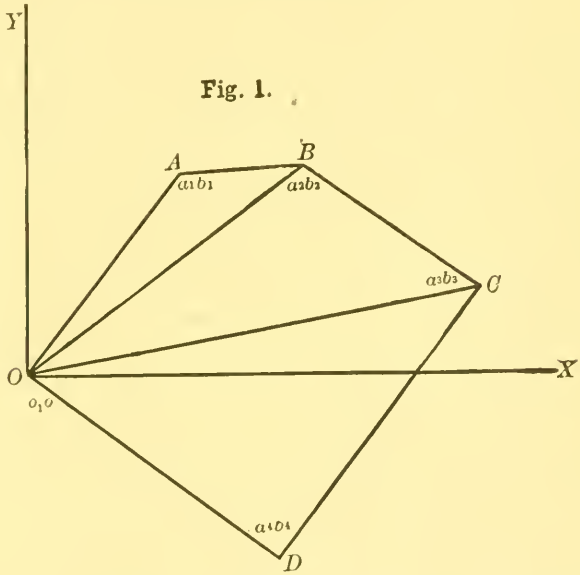


Fig. 1.

Let the rectangular co-ordinates of the points be $(o\ o)$ $(a_1\ b_1)$ $(a_2\ b_2)$ $(a_3\ b_3)$ $(a_4\ b_1)$. The area of the triangle $O\ A\ B$ expressed in determinants is

$$\frac{1}{2}\begin{vmatrix} a_1 & b_1 & 1 \\ a_2 & b_2 & 1 \\ o & o & 1 \end{vmatrix} = \frac{1}{2}(a_1\ b_2 - a_2\ b_1).$$

In like manner the area of $O\ B\ C$ is

$$\frac{1}{2}\begin{vmatrix} a_2 & b_2 & 1 \\ a_3 & b_3 & 1 \\ o & o & 1 \end{vmatrix} = \frac{1}{2}(a_2\ b_2 - a_3\ b_2).$$

And so on for all the triangles.

Collecting these results we have:

$$\frac{1}{2}\left\{\begin{array}{l} \quad a_1\ b_2 - a_2\ b_1 \\ +\ a_2\ b_3 - a_3\ b_2 \\ +\ a_3\ b_4 - a_4\ b_3 \end{array}\right\} \text{ which is the total area.}$$

By placing the abscissas of the several points in one column and the ordinates in another, we can obtain these results by simple multiplication.

Station.	x	y
A	a_1	b_1
B	a_2	b_2
C	a_3	b_3
D	a_4	b_4

Thus the positive products are indicated by the oblique lines beginning at the left and drawn downward: the negative products by the lines beginning at the left and drawn upward. If any of the co-ordinates are negative the signs must be taken into account in obtaining the products. In this example the most westerly station is taken as the origin, but in general, any point can be used as origin.

An example will serve to explain the method. Fig. 1 is the plat of the field, *O* being station 1, *A* station 2, etc.

Station.	Bearing.	Distance.	Latitudes.		Departures.	
			N +	S −	E +	W −
1	N 35° E	2.70	2.21	—	1.55	—
2	N 83½° E	1.29	.15	—	1.28	—
3	S 57° E	2.22	—	1.21	1.86	—
4	S 34¼° W	3.55	—	2.93	—	2.00
5	N 56½° W	3.23	1.78	—	—	2.69

So far we use the ordinary method. From these latitudes and departures we calculate the co-ordinates x and y.

Station.	x	y	Products.	
			+	—
2	2.21	1.55	6.2543	3.6580
3	2.36	2.83	11.0684	3.2545
4	1.15	4.69	3.0935	—
5	— 1.78	2.69	8.3482	—

$$\begin{array}{rl} 28.7644 & \qquad 6.9125 \\ \underline{6.9125} & \\ 2\,/\,\overline{21.8519} & \\ \underline{10.9259} & \text{sq: ch.} \end{array}$$

The x of station 2 is the latitude of that station which is 2.21; the x of station 3 is the x of station 2 plus the latitude of station 3, or $2.21 + .15 = 2.36$. Add the next latitude to this sum and the result is the next abscissa and so on. The last x should equal the last latitude, but with the opposite sign. The y co-ordinates are obtained in a similar way. The products are obtained by cross multiplication as stated above. The last x is minus and hence $- 1.78 \times 4.69$ will be plus, and will be placed in the first column. By using another station as origin the result can be proved. There are more multiplications by this method than by the method of double longitudes; but by using a three-place multiplication table such as *Crelle's Rechentafeln*, the work can be performed quicker. It has been stated that any point can in general be used for the origin. If, however, the lines drawn from the origin to divide the figure into triangles (these lines need not be drawn in practice) cross any part of a re-entrant angle, it is better not to use that point as origin. Simple inspection of the plat will usually determine which point or points had better not be used as origin. It would be easy to show that in the case where the lines from the origin do cross the re-entrant angle the method does apply by changing the sign of one of the triangles, but there are usually so many points from which to choose an origin that this is unnecessary.

AN ENLARGED WATERWAY BETWEEN THE GREAT LAKES AND THE ATLANTIC SEABOARD.

DISCUSSION.

Continued from Page 319.

BY WM. PIERSON JUDSON, M. AM. SOC. C. E.; M. INST. C. E.

The abstract of Mr. Corthell's paper, which the Directors of the Western Society of Engineers request me to discuss, presents the subject of an enlarged Waterway from the Great Lakes to the Atlantic, in a manner which cannot fail to lead toward a final action, which those who have been identified with Lake commerce, have long looked and worked for.

The fact that there are several lines upon which the Waterway may be made, is perhaps one reason why action has so long been deferred: the local interests connected with each possible route tending to scatter effective effort.

The subject has been repeatedly brought before the public. The writer has been connected, officially, with three different projects and estimates, which have been made by the United States Government for this work. In 1868, in 1875 and again in 1890, each project looking toward a ship-

canal connection of Lake Erie with tide-water, and each being upon a larger scale than the last.

This experience has perhaps led the writer to regard a ship-canal, rather than the ship-railway so ably advocated, formerly and now, by Mr. Corthell, as being the natural and necessary method for transporting a ship and her cargo toward tide-water, and this may prevent his doing justice to the practicability of a ship-railway for this purpose.

Certainly the day is past for condemning a project because it is new and untried, and all civil engineers will owe Mr. Corthell a debt of gratitude for his past able presentments of the subject, when his efforts shall bear their first fruits in the hoped-for successful working of the Chignecto ship-railway. When this enterprise proves commercially effective, there will thus be added another to the civil engineers' means of overcoming nature's obstacles.

At present, however, we have definite knowledge of the capabilities and cost of canals only.

The Sault Saint Marie Canal shows what can be done in improved methods of operation; methods whose absence is so conspicuous in the operation of the new Welland Canal.

With the further improvements which can now be made in methods of construction, the cost of a Ship-Canal between the Lakes will show a much better comparison with that of a ship-railway, than is indicated in Mr. Corthell's paper.

As to the ship-railway, of course the estimates and opinions of cost and efficiency must be taken unquestioned, as there are neither data nor experience on which to base a discussion.

It is difficult, however, to accept the conclusion that the cost of moving a ton of freight a mile on a ship-canal, is over three and one-half times the similar cost on a ship-railway.

But whether a ship-canal, or a ship-railway is finally adopted for the connecting link, it seems that the main question of getting freight through to tide-water will be much advanced, if the number of possible lines between the upper Lakes and Lake Ontario, which are now under discussion, can be narrowed down to one. To aid this, certain propositions will be stated, which can perhaps be agreed upon:—

1st. That the ship-canal, or the ship-railway, must be built and controlled by the United States Government.

Because the commerce of the United States is great and growing, and is only allowed to use the Canadian canals under intolerable restrictions and also because the money to build it can only be obtained from the United States Treasury.

2nd. That therefore the line must be located wholly within United States Territory:

Because annexation is too far off, and too uncertain, to be considered, even if the shortest, or cheapest, or best route lay through Canadian territory: which it does not.

3rd. That the line must be accessible to the commerce of all the great cities of the Lakes:

Because, if located in Georgian Bay, as proposed for Mr. Corthell's line, the opposing interests of the side-tracked cities of Detroit, Toledo, Cleveland, Erie, Ashtabula and Buffalo would impede or prevent the obtaining of the necessary appropriations from Congress, upon whose favorable action the supply of money for the work must depend.

Mr. Corthell asks whether artificial boundary lines shall be permitted longer to restrict our commerce. It is quite likely that, in the best possible world, such unnatural obstructions would not obstruct. But as this world is now constituted, an international boundary-line is an insurmountable obstacle to such a work, and a route which must cross it, will wait for appropriations until the boundary line disappears.

Aside from these most important financial considerations, the Huron-Ontario route, from Georgian Bay to Lake Ontario at Toronto, has natural disadvantages as compared with the shorter and quicker ship-canal route, from Lake Erie near Buffalo to Lake Ontario.

The Huron-Ontario route is 75 miles of canal longer, and has 130′ more lift, or 260′ more lockage. It has also the disadvantage of the late opening and early closing of navigation in Georgian Bay by reason of ice and fogs.

To offset this, the Huron-Ontario route requires 220 miles less open navigation through the Detroit River and Lake Erie: but this last saving of the Lake Erie trip, puts the great cities before named at one side, and thus ignores the commercial law that great transportation routes must touch commercial centers.

In referring to the Niagara Ship-Canal project, Mr. Corthell revises the official estimate of cost made in 1890, and increases it from 23 millions of dollars to 35 millions.

The writer himself made this official estimate of 1890, and is ready to agree with Mr. Corthell that it needs revision. But by materially reducing it, rather than by increasing it.

When making this 1890 official estimate, it was done under orders to take the lock of the Sault Sainte Marie Canal as its basis of cost; making due allowance for the proposed smaller size of locks. This was done; and the estimate total of 23 millions was thus arrived at.

This at once burdened the project with an excessive estimate. The proposed locks of the Niagara Ship Canal have little in common with the Sault Sainte Marie lock, and all points of difference are in favor of much less cost. The location of eleven of the eighteen locks in solid rock-cut upon the Niagara hill-side, leaves out of the question all coffer-damming and water disposal, and makes massive cut-stone lock-walls unnecessary.

The situation at Niagara is unique in ship-canal construction, and gives field for entirely new departures in such work.

The lock chambers can be excavated wholly in the rock, and the walls of the rock-cut can be faced with concrete, instead of being formed of the usual massive cut-stone masonary, costing vastly more.

All power for operating the rock-excavating and constructing machinery, can be generated from water power obtained by running a preliminary earth cut, along the summit line of the proposed canal, through to

its junction with the upper Niagara River near Tonawanda. While all drainage water and waste-water will take care of itself by natural flow through Olcott creek to Lake Ontario. Full benefit can thus be taken of all improvements in electric mining devices. In short, there is every reason why no former canal work can have been done as cheaply as this may be done, and there is every reason why the official estimate of 1890 should be reduced to, or below, the unofficial estimate which was made and published by the writer in 1888, while was 18 millions. This is, one half of the estimate now made by Mr. Corthell.

As Mr. Corthell's estimate of cost of operation includes interest upon the cost of construction, this correction would reduce his unaccountably large estimate of 12 1-2 mills per ton-mile for the transit of this canal.

This link in the chain, connecting the upper lakes with the lower lake, is the first one which must be built.

From Lake Ontario to the seaboard remains to be considered, and for this Mr. Corthell recognizes only the route by way of the St. Lawrence and its Canadian canals.

If the enlarged waterway is to be built by United States money, and traversed by United States vessels, then the St. Lawrence routes either to Montreal, or to Lake Champlain and thus to the Hudson, cannot be considered, for the 26 locks and the 47 miles of Canadian St. Lawrence canals must first be rebuilt and enlarged by the United States, at an estimated cost of 70 millions of dollars. This necessity would compel the finding of another outlet by enlarging the Oneida Lake and Erie canal routes, to the Hudson, for which full estimates have been made, which have been so often published that they need not now be repeated.

All who have read Mr. Corthell's paper will agree with him that an enlarged waterway to the Atlantic is needed, now, and must be made, and they will join with him in urging this need upon those who form our National policy.

November 26, 1891.

By J. M. Goodwin.

It has been suggested that I give some data in the matter of cost of transportation by steamer, (say of a cargo of grain from Duluth or Chicago to Cork or Liverpool), going "through," compared with cost of transportation by the practice in which the grain is transferred at Buffalo, or Oswego, to Erie Canal, and again at New York.

According to my view, this line of inquiry is precisely that to which the advocates of a "Lake and European" traffic should have applied themselves at the outset.

Traffic (*i. e.*:—regular commercial plying of vessels between Chicago and Liverpool, *via* St. Lawrence) is impracticable; even while such traffic has only the "small" Erie Canal as a rate-making competitor. With the "Erie" canal enlarged to (10′ water) 9′ navigation, with locks 22′×220′, the New York route would be "out of sight" superior to the St. Lawrence route.

I don't exactly get the "drift" when it is suggested to me that the

"Lake Erie & Ohio river" ship-canal "promotors" meet "difficulties" in approaching the subject of "deep-water" routes to the Atlantic. If it is intended to indicate that the public* is inclined to object to our projected *depth* of canal, (15′ of water), on the ground that *other* projected canals are (as per plan) to have 20′ of water, and that, *therefore*, our canal should have 20′, or thereabout; and that we find a difficulty in demonstrating, (to the entire satisfaction of the objectors), the facts that the said "other" canals are affairs with which *we* have no direct concern; and that while the "Michigan" canal, for example, will *necessarily* have 20′ of water, our canal need have no more than 15′, then I agree that you may properly, in this connection, use the term "difficulty." But, when the "Lake Erie & Ohio River" project comes to be critically examined with view to *decision* as to proper (or necessary) depth, the sufficiency of the 15′ depth will quite certainly be established. With our locks (300′×45′ in the clear, with 15′ on the sills), vessels carrying 3,000 tons may use the canal. Vessels for lake navigation need *beam*, rather than depth, to get carrying capacity. And with vessels, as with other vehicles, there is a point at which increase of size reaches its limit in the direction of economy in practical operation of the vessel, or vehicle. But in the case of our "Lake Erie & Ohio River" canal there are natural conditions, limiting depth, that are, necessarily, to be taken into account. I am of opinion that a 15′ canal will amply, and in every way satisfactorily, serve the traffic for which the Lake Erie & Ohio River Canal is to be built. Could I see that the canal with depth of 18′ would serve *materially* better than with 15′, I should not hesitate to recommend a very considerable expenditure for purpose of securing the additional 3′. But, as I have said, I believe that the 15′ canal will satisfy every *real* demand of the situation.

As to the *Lake-European* traffic, by steamer, direct from Chicago to Cork or Liverpool. You say that "personally" you would like to see discussed "the items of cost in steamship transportation;" and "how these items vary with distance;" and other circumstances. You ask:—"What are the values of time and outlay in port; and of expenditure while under way," etc. On pages 20 and 21 of my pamphlet entitled "Panama Ship-canal and Interoceanic Ship Railway projects, 1880," you may find statement of British Light-house dues; Liverpool pilotage-fees; U. S. "Tonnage" and "Hospital" dues; New York pilotage rates; (winter and summer); New York wharfage and dock charges; and some of the port dues of New York. These items of information, with the explanatory remarks in connection therewith, will be of use in making certain estimates. The line of inquiry which you suggest is, in my view, precisely that which a person—conceiving the notion that a certain line of traffic is particularly desirable—should *at the outset*, take up.

Granted a waterway affording a route by which a steamer may carry 3,000 tons (net) of grain from Chicago to Liverpool, *via* the "Niagara" Canal and the St. Lawrence River. Immaterial what the depth of the (interspersed) canals is, as long as it is *enough* to pass the 3,000 ton-carrier.

*Engineering public.

We assume that the vessel would have no "*tolls*" to pay for canal, nor river facilities; and (of course), that she would go through without breaking bulk anywhere *en route*. Our object being to determine whether or not a lake steamer, of 3,000 net tons carrying capacity in lake navigation, would use this route, we need not examine particularly into the value of the several items going to make up the aggregate cost of a trip over the route. The prime question is:—Would the route afford the steamer an opportunity for *making more money* in a "season," than she can make in lake navigation. If she can earn more money *gross*, in a season, in the lakes than she can in the European trade, she can, of course, earn more *net*; because the items of "wear and tear," port charges, and several others, will be greater in the European than in the lake, trade. At the outset we must take into consideration and account, the fact that she cannot offer freights any better *dispatch* than they get, or may have, *via* New York. In May, 1890, a cargo of oats went from Duluth to New York in six (6) days. Steamer *North Wind* to Buffalo, (997 miles); thence rail to New York, (440 miles). Total = 1437 miles; average speed:—within a small fraction of 10 miles per hour. Allowing one day for transfer at New York, and 8 days ocean passage, this cargo might have been in Liverpool within 15 days from time of leaving Duluth. "Time" freight may readily go from Chicago to Liverpool within 12 days; (by rail to New York); Even if making the (entirely impossible) rate of ten (10) miles per hour throughout the *entire trip* from Chicago to Liverpool the lake steamer would consume 18.7 days in making the trip, (4,488 miles.) A cargo going from Chicago to Liverpool, *via* steamer to Buffalo, and *canal boat* on Erie Canal and Hudson River to New York, may *readily* make the trip, through, in 21¼ days; as thus:—

Chicago to Buffalo	63.5	hours.
Transfer at Buffalo	12.0	"
Canal to Albany	192.0	"
Albany to New York	26.0	"
	293.5	hours = say 12¼ days.
Then one day for transfer at New York		1
Then eight days ocean		8
		21¼ days.

In order to equal *this* rate the lake steamer would have to make 8⁸⁄₁₀ miles per hour throughout the *entire trip*, or speed equivalent to that

In view of the facts we must conclude that our lake steamer could command *rates* only equal to, (*if* equal to) those *established by the Erie Canal* practice; that is to say, on *grain*, for example. Now what costs the transportation of 100,000 bushels of wheat from Chicago to Liverpool *via* New York. Lake rate is about 1³⁄₁₀ mills per ton mile—say rate on wheat is 3 cents per bushel, Chicago to Buffalo, (33⅓ bushels × 3 cents) = $1.00.

Per net ton	$1.00.00 per ton.
Transfer at Buffalo (½ cent per bushel)	0.16.66 " "

Canal rate 3 mills per ton mile	1.48.20 " "
Unloading at New York ½ cent per bushel..... Weighing at New York ½ cent per bushel...... Loading and trimming at New York 7/10 cents per bushel..............................	0.56.66 " "
Ocean freight 1 mill per ton mile, 3,000 miles, (9 cents per bushel)........................	3.00.00 " "
Say wheat worth $1.00 per bushel:	
Insurance 4 mills per bushel.................. Commission 5 mills per bushel.................	0.30.00 " "
Aggregate cost...............................	$6.51.52 " "

Or *say*, 19.55 cents per bushel:

Total cost:—100.000 bushels = $19,550

Freights alone, cost $5.48.2 per net ton = 16,446

The lake steamer would have to carry the 3,000 net tons of grain 4,448 miles for $16,446, or at rate of $3.66.443 + *per mile*, which is equivalent to 1.221 + mills per ton mile, which is materially less than the average *lake-rate*. The cost to the *owner of the grain* would be the $16,446 *plus* insurance. This item would be materially greater for the Gulf of St. Lawrence voyage than for the New York-Liverpool voyage. Insurance would be *at least* $1,000—making cost $17,446. This would be all right for the *owners of the grain*; but how about the ship? She, also, must pay extra insurance; must pay (extra) British light-house dues; pilotage; and port charges, not involved in her *lake* business. If she registers 2,500 tons her light-house dues would be $750 *per year*. If she draws 16′, her pilotage at Liverpool, "in" and "out," would be $153.60, for the voyage. I do not know what the Gulf of St Lawrence pilot charges are, and with all these expenses, and extra "wear and tear," she is getting a *less* ton-mile rate than that which she commands *in the lakes*. The ship could not, by any possibility, make more than *5* round trips in a St. Lawrence River "season"—say *200* days. If she made 5 trips she would, (at the above specified rate), earn $16,446 × 5 = $82,230; and if she had *good luck*, might get 25 % of that sum for return cargoes, thus earning, in all, $102,787.

Carrying 100,000 bushels of grain from Chicago to Buffalo @ 3 cents per bushel (=$3,000), and 2,000 tons cargo back freight @ $1.00 per ton (= $2,000), she makes, in lakes, $5,000 per round trip; and in season of *214* days (limiting the season to Erie Canal extent) can easily make 27 round trips, and earn $135,000. As the owner of the grain would save the difference between $17,446, and $19,545.60, (cost of 100,000 bushels going *via* New York, as aforesaid), provided his grain went by *St. Lawrence route* by the steamer charging only *1.221 + mills per ton mile*, you will say that the grain owner might afford to pay that difference (viz: $2,099.60) to the steamer. This "difference" is equal, say, to 2.1 cents per bushel.

The *$16,446*-rate of the steamer, is equivalent to 16.44 + cents per bushel; and the addition of the 2.1 cents would make the rate 18.54 cents per bushel. At this rate, carrying 5 trips (= 500,000 bushels) the steamer would earn, on the grain, $92,700, and, allowing $20,557 as before, for re-

turn freights, she would earn, in all, $113,257. She would *still* be $21,743 *behind her lake earnings.*

The foregoing indicates the reasons why lake steamers will not engage in European trade. In a letter to Mr. Edward P. North, Member A. S. of C. E., of New York, I lately set forth in a calculation similar to that herein made, the reasons why lake steamers would not engage in a lake and Atlantic seaboard traffic, even were there a canal with 20′ of water extending from Buffalo, or Oswego, to Albany. The conditions under which canal-boats (barges) would *keep rates down* on the "enlarged" Erie Canal, will not obtain in the case of the "Lake Erie & Ohio River" ship-canal; and the length of the said ship-canal is not so great as to render the expenditure of time, necessary to round trips through the canal, by a large lake steamer, unduly great in comparison with the advantages gained by such trip. One of the principal advantages, so gained, is the securing, at amply remunerative rates, of a *return cargo* of coal destined for the northwest port to which the steamer is to return for *one*. This matter is quite fully treated in the report of the Lake Erie & Ohio River Ship Canal Commission, of which you have a copy. The cost of operation of a modern lake steamer, of large size, and of sailing vessels also, in ore and coal freighting, is explicitly set forth in said report, pages 103 to 111.

I note what is said to the effect that *depth* in lake vessels is more expedient than *beam*. Suppose you have a lake of depth of 15 feet, and wish to carry cargoes of 3,000 tons on such lake. Suppose circumstances (canal-locks for example) limit the *length* of vessel to 300 feet. With *steel steamer* 300 feet long with 45 feet beam you can carry 3,000 net tons on 14 feet draft: (suited to your lake). Will you build the vessel 45 feet beam or will you insist upon making her only 40 feet beam, and thus make necessary an *increase of the depth of your lake by about 2′ 9″?* A steel steamer 337′×42′ carries 3,000 tons on 14′ of water. If your locks were (as before supposed) only 300′ long, make the steamer 300′×45′, rather than insist on the 42′ beam at expense of deepening the whole lake.

You say that Chicago-Buffalo "liners" are carrying freights at less than 1.2 mills per ton mile. They can afford to do so; and they could afford to carry, on lake or ocean, at 1 mill per ton mile. But the question in connection with the Lake-Ocean route is:—Can a steamer make as much money on the Lake-Ocean route as on the *Lake* route. Take your steamer carrying 5,000 tons; make her rate 1.2 mills per ton-mile Chicago to Buffalo. Never mind "back-freights." She makes 27 trips per season, and earns $144,018. Now let her get 1.2 mill to Montreal (1,263 miles), and 1 mill from Montreal to Liverpool (3,225 miles). She can, perhaps, make 5 trips. She earns then $118,515, or $25,503 less than on the lakes. Worse than useless to figure on increase of number of round trips to Europe and return. We must take the conditions (governing in the matter) as they are; not as we wish they might be. If you *could* add another round trip to Europe, I would put my Chicago-Buffalo trips up to 31 instead of 27. The 31 trips may be made without extravagant outlay for speed. The "Union" liner Oswego in 1890 made trip Buffalo to Chicago in 57 hours; in 1889 she

made the same trip in 55 hours, 15 minutes, and nearly, or quite, as good time has been made by other ships.

There need be no fear that ocean vessels "will come into the lakes, and knock the bottom out of rates." Precisely the conditions that will keep "lake vessels" in the lakes will keep ocean vessels out of the lakes. There are several (perhaps many) lake built vessels in service in the Atlantic; but I do not know that any vessel has ever made more than one round trip between the upper lakes and Europe; or between the lakes and an Atlantic port. It is said "the lake vessel would have twelve month's employment if she could get to the ocean;" same as the ocean vessel. So she would, but it would not be in lake and ocean trade, but in ocean trade or in trade now carried on by ocean steamers. In extreme cases the St. Lawrence navigation, to Montreal, extends to seven months of the year. Erie Canal navigation averages 214 days. Lake Erie, etc., 210 and 230 days. Your "great waterway" must be idle about 41 per cent. of the time, at best.

By Samuel McElroy.

This important problem, which is to be solved sooner or later, between the Great Lakes and the Ocean, as presented in past years in various forms to state Legislatures and Congress, and which Mr. Corthell's elaborate paper has presented to the Society for discussion, is worthy of careful study, liberal design and large outlay. My own views are conservative, and my connection with it, on the part of New York state, at Niagara and in the Hudson valley, a number of years ago, makes it interesting to me.

All engineering projects, sooner or later, find themselves controlled by and subordinate to general principles of construction, and of the operation which really controls it. There are two chief methods of transportation at issue here, water and land; across the great lakes and down their connecting outlets and canals, or across the ocean, water transportation is a necessity, and without question it is the best and cheapest. Nature and experience have fully established that law.

Under this law detailed principles of economy in operation command. Thus the simple law of reduced cost with enlarged capacity of hull, has been making and must continue to make continuous increase in the size of ocean vessels, and plans which are well enough to-day, as to locks, canals, etc., ten years hence are likely to become entirely inadequate, especially since naval architects find increased beam consistent with increased speed.

Is it wise then to attempt any outlay sufficient to carry large class ocean vessels, without break of bulk, to Chicago? If to-day it is entirely impracticable for the best models in use what is the future likely to require? Engineers are constantly warned by experience that twenty or thirty years are only a step, as to time, but a revolution as to plans and methods.

In arranging the plans for the Niagara ship canal in 1854, and the Hudson River in 1867, we were controlled by certain local depths of navigation, notably the St. Clair flats. Examination of the St. Lawrence above Quebec shows that the reasonable limit of draft is not over 20 feet;

and practically, that may be taken as the standard for any increased outlay likely to be made from the Atlantic to Chicago. This excludes the best ocean hulls for lake transit.

The lake experience has however developed a principle of transportation which obviates any regret, commercially, as to this exclusion of single ocean steamers.

A remarkable difference exists in practice between the power exerted by a vessel in self propulsion and that required to tow it at the same speed and displacement. The gain, in some cases, is claimed at fifty per cent; in every case there is a large gain. This is due to defective action of machinery; to burying the hull, (Umbria, 500×57.2×22.5′ "moulded draft," said to bury 2′); to wave reaction, and other causes.

On the great lakes, then, vessels properly sparred and manned to take care of themselves in a storm, of 2,000 tons and over, towed in fleets of four or five,by a steamer of the same tonnage,hull 300×41×14′ draft,realize the highest efficiency and economy of transportation which they have brought down to ½ mill per ton-mile, in rate, equalling that of the best single ocean steamers, and being one-fifth that of first-class trunk railways.

As there is no difficulty in transferring this system to the ocean, if there is any special objection to break of bulk for cargoes once loaded, the condition of our water way certainly suggests the continuation of the lake system across the ocean.

This also suggests the necessity of adopting, by common consent, a fixed standard of water-way draft and dimensions, adapted to such a system of continuous navigation.

Above a certain size and weight of hull, the trouble in handling vessels in narrow channels, basins or locks rapidly increases, and affects time and liability to damage. If the hull of about 300′ by 14′ draft, under the charge of a powerful tug, will rival the largest ocean hulls in economy, their transit through artificial structures certainly should tend to keep down dimensions where quickness and safety of motion are important elements of economy.

The lock size adopted for Niagara in 1854 was 300′×70′×12′; by the plan of 1867, 400′×80′×21′. With the St. Clair flats deepened to 20′, as proposed, and the Sault Ste. Marie at 20′, there are obvious advantages in the same depth at Niagara for lake commerce, and in rock cut it is easily made. Whether any larger lock dimensions are necessary is a problem lake commerce alone should determine.

A glance ot ocean hull standard is significant on this question. The new Cunard steamers to be built are 600′×65′, 14.000; load draft will be 25 to 27′. The City of Rome is 542.5′×52′, 8,144 tons; Servia 575′×52′, 7,392 tons; Umbria 500′×57.2′, 7,800 tons; Teutonic 556′×57.5′; very uncomfortable conditions for narrow prisms or lock gate entrance, or rapid handling.

The interests of the city and state of New York: long opposed by the city of Buffalo, certainly require adequate inland water transportation on a proper scale, which is, of course, the lake minimum of 14′ draft. Such

transportation is impracticable from Buffalo or Oswego, but comparatively easy from the St. Lawrence through Lake Champlain to a point on the Hudson below Albany.

If this state could by some proper diplomacy acquire the territory to the center of the St. Lawrence and the Richelieu rivers, an admirable suggestion of Mr. Corthell's might be carried out, viz: to leave the St. Lawrence by ship canal at the proper level (about midway on the Beauharnois canal), to enter Lake Champlain, a line of about forty miles. Such a construction within the present state territory would be far more expensive, with a line of about sixty miles long. That it is the duty of the state to build the Niagara Canal, it is to be hoped the New York City representatives will see, at no distant day.

As to the use of a ship railway for ocean hulls, even as they now are, there are serious questions. From my experience in special charge of the Brooklyn Navy Yard Dry Dock, I know that even where shoring is regulated by gradual water pumping within a firm granite dock the proper support of a large hull is a difficult and slow problem. To substitute detached shores and supports for water flotation without straining a hull, of necessity unequally loaded, involves great care with favorable benches. To change this for a flat form in motion on varying grades over a railway whose roadbed must greatly vary in condition and resistance, subject in transitu to storms and other variable resistances, certainly adds greatly to these difficulties. Unless there is some extraordinary gain to be secured, as in isthmus transit between two oceans, it is difficult to see much promise of general use for such transit.

Genius and money, however, are capable of overcoming great difficulties, and to say that such transit requires great care in design and operation is not to say that it is at all impracticable.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

SEPTEMBER 16, 1891.—A regular meeting was held at the American House, Hanover street, Boston, at 19:35 o'clock. President Stearns in the chair. Fifty-two members and nineteen visitors present.

The record of the last meeting was read and approved.

Mr. Edward G. Chamberlain was elected a member of the Society.

The amendment to Article II of the Constitution, adopted at the last meeting, striking out at the end of the third clause the words "and shall not be entitled to vote," was ratified, 34 in the affirmative and 1 in the negative.

On motion of Mr. FitzGerald, the Secretary was requested to convey the thanks of the Society to Mr. Allen Hazen for his valuable paper read at the June meeting.

The Librarian announced the gift to the Society of three boxes of books from Col. C. W. Folsom.

President F. P. Stearns read the paper of the evening entitled. "The Selections of Sources of Water Supply" The reading of the paper was followed by a general discussion upon the subject of the paper.

A Pressure gauge tester manufactured by the Crosby Gauge Valve & Co., of Boston was exhibited by Mr. J. R. Freeman who stated that he had had this instrument in use for six months and considered it by far superior to any other apparatus for this purpose which he had ever seen.

The speaker believed it to be fully equal to a first class Mercury column in accuracy and much superior to a Mercury column in convenience and quickness of manipulation.

The apparatus consists principally of a scale-pan for weights, which rests on a steel piston turned and ground with great accuracy to a diameter which gives one fourth of a square inch in area.

The cylinder containing this piston communicates with a tube leading to the pressure gauge to be tested and thus if a weight be placed on the scale pan such that together with scale pan it weighs 10 lbs., the pressure per square inch will be 40 lbs. and by observing where the needle of the gauge stands, we see how great is its error.

A series of weights accompanies the instrument by which any pressure up to 200 lbs. per sq. inch (varying by intervals of 5 lbs.) may be obtained.

The friction of the piston is wholly eliminated by spinning the scale-pan around whereupon it settles to its true position, and the marvellously simple and beautiful way in which this rotating of the piston eliminates the friction, is the key to the success and accuracy of the instrument.

By test with various micrometer callipers Mr Freeman had satisfied himself that this piston did not differ by one thousandth of an inch from its true diameter, and by comparsion of the scale-pan weights with the best official standards, he felt sure they could at most be but a few grains in error and he had no doubt that the instrument would tell the truth within less than one tenth of one per cent. when used with proper care.

This apparatus does away with the doubts and questions relative to specific gravity of the mercury, the effect of capillarity, the varying size of tubes and uncertain lowering of cistern, in a mercurial gauge, is ten fold quicker of manipulation and the result of Mr. Freeman's experience led him to commend it highly to the members of the Society.

Adjourned S. E. TINKHAM, Secretary.

OCTOBER 21, 1891:—A regular meeting was held at the American House, Hanover street, Boston, at 19:45 o'clock, President Stearns in the chair, sixty-four members and nineteen visitors present.

The record of the last meeting was read and approved.

Mr. Arthur C. Walworth was elected a member of the Society.

The President stated that Mr Moore of St. Louis would probably read a paper at our January meeting, if arrangements could be made to hold the meeting on some other evening than the third Wednesday, and called attention to the fact that there was no provision made in the By-Laws for any change. Mr FitzGerald suggested the advisability of holding the January meetings of the Society on some other day than the third Wednesday for the reason that the American Society of Civil Engineers holds its annual meeting on that day and a number of our members desire to attend those meetings After a discussion of the subject and an informal vote showing a preference for the fourth Wednesday, Mr. FitzGerald proposed in writting the following amendment to By-Law.

Regular meetings of the Society shall beheld on the fourth Wednesday in January, and on the third Wednesday of the other months, except July and August. unless otherwise provided by vote of the Society at a previous meeting.

Professor Dwight Porter gave a brief description of the Chignecto Ship Railway, which is designed to afford vessels of not more than 1000 tons. a short route from the Gulf of St. Lawrence to the Bay of Fundy. Lantern views were shown, illustrating the general location of the works, the progress on the lifting dock at Amherst or western terminus, the arrangement of hydraulic machinery in the power house and other features of the undertaking.

Professor Thomas M. Drown gave an interesting account of the more important papers read at the International Congress of Hygiene and Demography held in London in August last and followed it with a description of several sewage farms in England visited by him during the summer.

Adjourned, S. E. TINKHAM, Secretary.

NOVEMBER 18, 1891:—A regular meeting was held at the American House, Hanover street. Boston at 19:45 o'clock. President Stearns in the chair. Fifty-nine members and twelve visitors present.

The record of the last meeting was read and approved.

Messrs. Charles R. Cutter and William J. Luther were elected members of the Society.

The amendment to By-Law, proposed at the last meeting, so that it shall read, "Regular meetings of the Society shall be held on the fourth Wednesday in January, and on the third Wednesday of the other months, excepting July and August, unless otherwise provided by vote of the Society at a previous meeting," was adopted by a unanimous vote.

On motion of Mr. Brooks, it was voted to hold the January meeting. on Monday January 18, 1892.

The Secretary read a communication from the committee on International Congress and Engineering headquarters, Columbian Exposition, stating that the estimated expense of maintaining the proposed reception rooms and employing a secretary and necessary assistants, was $15,000 and that Society was requested to contribute $550, as its proportion. On motion it was voted:—That the Secretary be requested to send to the members a circular in relation to the Society's subscription to the fund for maintaining an Engineering headquarters at the World's Fair, with a statement of the amount which this Society is expected to contribute and the proportional part per member, the circular to contain a blank form for members to use in returning their subscriptions.

Professor William T. Sedgwick spoke on "Aspects of European Sanitary Science" which special reference to water pollution and purification in relation to certain germ diseases. A brief description was given of the water-filter at Berlin and the system of sewage-disposal by irrigation, as practiced in that city.

Professor R. H. Richards exhibited and explained a new form of stadia telescope lately devised by him and Mr. E. P. Adams presented some charts for facilitating calculations in stadia work.

Adjourned, S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

353D MEETING. NOVEMBER 4, 1891.—The club met at 8 p. m. at the club rooms. President Burnet in the chair and twenty-four members and five visitors present. The minutes of the 352d meeting were read and approved.

The executive committee reported the doings of its 117th meeting.

Mr. Charles W. Stewart was elected a member of the club. Mr. L P. Butler was proposed for membership.

Circular No. 1 of the Executive Committee of Engineering Societies, Columbian Exposition, was read and referred to the executive committee.

The president announced that owing to sickness Prof. Nipher was unavoidably prevented from being present, and his paper on "Some Properties of a Field Force" would therefore have to be laid over for some future occasion.

Prof. Johnson made some remarks on the question of the proper education of engineers and what degree should be conferred upon the completion of their college course. Prof. Johnson thought it a question if the college course was not sometimes too long, and gave some statistics of the engineering schools throughout the country tending to show that the policy of the present day was rather towards decreasing instead of increasing the course. Prof. Johnson then introduced Chancellor Chaplain of Washington University.

Prof. Chaplain thought that the question raised by Prof. Johnson had two sides, and in considering it the public and their needs should be given full weight. The public regarded all courses as very much alike, and greater numbers would be attracted by the shorter course, and one of the questions was whether the greater numbers were not better for the country. The whole subject, however, had many points to be considered.

Mr. Holman thought there was no question but what an engineer's education at the present day should be as thorough and as complete as possible. Whether the course should be three, four or five years should depend on the point at which the course commenced.

Mr. Seddon said that one of the uses of the college should be to give enough of the work in order to satisfy the student that he was capable of undertaking the profession of an engineer, or, in other words, sift out those unsuited for the profession.

Further remarks followed by Messrs. Burnet, Woods, Bouton, Olshausen, Ferguson and Thacher.

Adjourned. ARTHUR THACHER, Secretary.

355TH MEETING. DECEMBER 2, 1891. The club met at 8 p. m. at the club rooms, President Burnet in the chair, and fifty-one members and two visitors present. The minutes of the 354th meeting were read and approved.

Verbal reports were presented by the standing committees, and on motion the reports were accepted and the Committee on Library and Reading Room and the Committee on Revision of the Constitution and By-Laws were discharged.

The Secretary, Treasurer and Executive Committee presented their annual reports.

The report of the Treasurer was referred to the Executive Committee to be audited.

The committee on nominations for officers for 1892 presented the following report:

St. Louis, Mo., Dec. 2, 1891.

To the President and Members of the Engineers' Club of St. Louis:

Your committee, selected to nominate a list of officers for the year 1892, respectfully report as follows:

For President—J. B. Johnson.
For Vice-President—B. L. Crosby.
For Secretary—Arthur Thacher.
For Treasurer—Chas. W. Melcher
For Librarian—R. E. McMath.

For Directors—George Burnet, B. H. Colby.

For Board of Managers Association of Engineering Societies—J. B. Johnson, J. A. Laird.

For the entire committee C. M. Woodward, Chairman.

On motion the report was accepted and nominations were closed.

Prof. Johnson exhibited a specimen of Tobin bronze which he had been testing, and which had shown remarkable strength.

For the next meeting, December 16th, an address by President Burnet and a paper on "The Action of the Reciprocating Parts of High Speed Engines," by Prof. A T. Woods, were announced.

At the close of the meeting the members of the club adjourned to the Mercantile Club, where arrangements had been made for an informal supper. After partaking of the supper, President Burnet called on the charter members, ex-presidents and other members and visitors for remarks. Col. Flad, Col. Meysenberg, Mr. Fisher and Mr. Wise, the only charter members still remaining with the club, ex-presidents Woodward, Moore, Potter, Holman, Meier and Nipher; Prof. Chaplin, Mr. See, Mr. Jewett, Prof. Johnson, Mr. Pitzman and others responded with appropriate remarks, and at 11:45 the meeting adjourned.

Arthur Thacher, Secretary.

The Secretary presented the following report:

St. Louis, Mo., December 2, 1891.

To the Members of the Engineers' Club of St. Louis:

Gentlemen.—The records of the club show the following statistics for the past year:

Eighteen meetings have been held; fifteen at the club rooms, Odd Fellows' Building, two at Washington University and one at the Elks Club. President Burnet occupied the chair at twelve meetings, Vice-President Eayrs at three, Prof. Nipher at two, and Mr. Russell at one. The total attendance of members was 498, or an average attendance of twenty-eight members. We have also had with us fifty-four visitors. The total number of recorded meetings is now 354.

Twenty papers have been read by the following members: Messrs. Seddon, Kebby, Ockerson, Turneaure, Perkins, Russell, Curtis, Bruner, Gayler, Farnham, Laird, Burnet, Dr. Adams, Col. Meier, Profs. Nipher, Howe, Kinealy and Johnson.

Sixteen new members have been elected and three old members have been reinstated. The club has lost sixteen members; ten by resignation, five dropped for delinquency, and one by death—that of Mr. S. F. Burnet. The present roll of the club shows that we have 131 resident members, 45 non-resident, and one honorary member and four elected but not yet qualified.

Respectfully submitted, Arthur Thacher, Secretary.

The executive committee presented the following report:

St. Louis, Mo., December 2, 1891.

To the Members of The Engineers' Club of St. Louis:

Gentlemen.—During the past year your executive committee have held twenty-two meetings. Eight papers presented at the meetings of the club have been approved for publication in the Journal. Forty-eight bills have been approved for payment. The expenses of the club have been as follows.

For the Journal	$ 518 97
For rent	470 50
For printing	197 65
For furniture	248 66
For miscellaneous	118 78
Total	$1,554 56

Seventeen applications for membership have been examined and sixteen were approved. Ten resignations have been accepted, and five names have been dropped for delinquency.

The following papers have been offered for the coming year:

"The Recent Survey of St. Louis; Its Methods and Results."—B. H. Colby.
"Pollution of Hudson River."—Prof. C. C. Brown.
"The Progress of Mapping in Missouri "—Arthur Winslow.
"Method and Results of Precise Leveling."—O. W. Ferguson.
"Elements Involved in Rapid Transit."—B. F. Crow.
"The Construction of Electric Railway Power Stations."—B. J. Arnold.
"Maximum Stress in Draw Bridges."—Prof. M. A. Howe.
"An Inclined Cable Railway for Transferring Freight Cars between the Upper and Lower Yards of the Western Cable Railway Company."—Edward Flad.
"Steam Generators with Hydro-Carbon Fuels."—Dr. Wellington Adams.
"Steam Shovels and Steam Shovel Work."—E. A. Hermann.
"Notes on the Harcuvar Pipe Line."—Frank Nicholson.
"Tunnel Timbering in Soft Ground."—Fred. W. Abbott.

The club is too large for the committee to hope to make an effectual personal appeal for papers, but it is expected that every member will interest himself in this matter and help to secure a full and varied programme for the ensuing year.

Respectfully submitted, GEORGE BURNET, President.
ARTHUR THACHER, Secretary.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

SEPTEMBER 29TH, 1891.—The Committee on Visiting Day appointed at the last meeting of the Club, selected this as the first Visiting Day of the year. At about 1:30 in the afternoon, members and guests, to the number of 37, met at the Club Rooms. The committee had arranged the following program, which was strictly carried out:

Meet at Club Rooms at 1:45 p. m. city time, Leave Club Rooms at 1:55 city time, sharp. Take cars (Detroit, Franklin Avenue, or Bridge Street cars) via Detroit to Kentucky Street, thence to Water Works, arriving at 2:30; leaving at 2:45; thence to Globe Iron Works Co's yard, leaving at 3:30; thence to Ship Owner's Dry Dock, leaving at 3:50; thence to Walker Manufacturing Co's Works, leaving at 5:30 p. m.

At the Water Works pumping station' Superintendent Whitelaw and Mr Kingsley explained the construction and operation of the works as well as possible, during the short visit. At the Globe Works Mr. Luther Allen met and escorted the party through every department of this large ship building plant. After a short stop at two of the largest dry docks on the lakes, the party proceeded to the works of the Walker Manufacturing Co., where it was met by Mr. E. R. Perkins, Mr. W. H. Bone, and shown through every department of these large works.

The day was pleasant, and every one was well pleased with the afternoon's work.

A. H. PORTER, Secretary.

OCTOBER 13TH, 1891.—Club met at 8 o'clock p. m., with President Gobeille in the chair, 42 members and visitors present. The minutes of the last meeting were read and approved. The President appointed Messrs. Kingsley and Bowler as tellers to canvass the ballots for new members. The Executive Board reported to the Club, Messrs. A. Schneider and C. C. Dewstoe, and recommended their election as Associate members. Mr. C. M. Barber made a report on the last Visiting Day. He also reported on new and more commodious Club Rooms, and stated that the prospect at present looked very bright and promising.

Prof. C. H. Benjamin read the following:

Report of visit of The Civil Engineer's Club of Cleveland, to the Works of the Walker Manufacturing Co., September 29th, 1891.

I make this report from my own personal observation, but I had only one pair of eyes to see with, and I find that one pair of eyes was very inefficient, as there was so many new and novel things to witness.

As we climbed the hill, leading to the massive pile of buildings, owned by this

firm, we saw the national flag slowly rising on its staff above the entrance. We were met by Mr. Perkins and conducted through the works. In the corridor we saw at one side the rack displaying the time-cards of the men, each bearing its appropriate number, and could imagine that a man who came in late and found the window down, would feel like a very foolish virgin indeed. On entering the offices our attention was particularly called to the excellent system of fire-proof vaults, in a large room at one side of the offices, separated from them by double doors with combination locks, and from the shop on the other side by a solid brick wall. The vaults are ranged on either side of this room, each having a fire-proof door, and being a vault within a vault. The same system is carried up to the floor above, where the vaults are used for the storage of drawings being fitted with suitably indexed drawers for that purpose. The drawing room adjoining, and immediately above the offices, is well lighted and well equipped.

We were particularly interested in some ingenious adjustable drawing tables, with sliding rulers attached. An excursion into the third story revealed a blue-print room, with a whole battalion of printing frames, waiting to be trundled out of the wide gallery outside. After inscribing our names in the visitors' book, we were ushered into the main shop, where we first noticed the extreme height of the roof, giving more the appearance of a cathedral than a machine-shop. When, however, we found pulleys 32 feet in diameter, in process of construction, we understood the need of high walls. The buildings are of the most recent type of machine-shop construction, with trussed roofs of iron and glass, the shafting at each side, and the wide center bays spanned by power traveling cranes. Some of us who were from New England wondered what would be the effect of an old fashioned snow-storm on that kind of a roof. The frontage of the buildings is 440 feet, and the length varies from 120 to 430 feet, the most of the shops being 290 feet long, and the total area roofed in is nearly 3 acres. We all stopped to see the massive grooved drum, 32 feet in diameter, and weighing over 70 tons, slowly revolving in the big-pit-lathe, with eight tools cutting at once, four on a side, and were still more impressed when the man in charge told us that 15 tons of chips had just been removed from its mate in the same lathe.

Before leaving the machine-shop, Prof. Roberts requested us all to remove our hats and put on a pleasant expression:—he pressed the button and we did the rest. On our way out of the shop, we stopped to glance at the open-sided planer, and the big boring-mill, slowly digging away at their appointed tasks, and then most of us went into the foundry, to see the process of moulding large gears by machinery for which this firm has become celebrated. The exact duplication of tooth after tooth in precise place on the rim, without the use of an expensive pattern, makes the machine-moulder a dangerous rival of the automatic gear-cutter in the other building.

We found here the same type of building construction, the same obedient cranes always traveling from place to place. In an adjoining room, we found two hydraulic-pumps and an accumulator, working under a pressure of 1,000 pounds to the square inch. Also the triple piston-blower, which furnishes the blast for the cupolas. A stroll into the old shops was rewarded by seeing the action of a power air-cushioned hammer, which would strike either heavy or light blows with the same precision and rapidity.

From here, some of us went to the engine room, where we found a Harris-Corliss engine carrying a grooved drum instead of a belt wheel, and driving the shafting by plies of manilla rope.

A glance into the boiler-house revealed the Brightman stokers slowly kicking down stairs a mass of glowing pea-coal.

As we were leaving the works, many of the number expressed their pleasure with the visit and their appreciation of the courtesies shown them, only regretting that the time was so short, in which to see so much. The writer was so much impressed with this that he went again the next day with a class of students from the school.

Respectfully submitted, C. H. BENJAMIN.

MR. WALKER:—I appreciate the pleasant way in which you have spoken of our

works. I am sorry I could not have been present at the time, but I was called away to Cincinnati.

To say that the works as a whole is the fruit of patient toil and thought is not exaggerating it in the least. It takes a great deal of time and attention to build up such works as ours. There is one new and interesting feature in our works, that is, the system of welding iron by using a blowing engine instead of a blower. The idea is to get the greatest amount of air at low pressure

Week in and week out we are melting 13 1-10 pounds of iron per pound of coke. Our melting zone is as low down as possible, making the capacity as great as possible.

We are building for the Third Avenue Cable Railway, four pulleys, 22 feet in diameter and four more 9 feet in diameter This entire plant is a repeater. We are not obliged to stop an engine to change over to any one of the four engines or drive any one of the four cables. The gripman uses either one of the grips or uses either cable separately without interfering with the motion of the engine, and all the other works can be going on while these changes are taking place.

This plant, as a whole, will be the best known cable system in the world.

The same plan of moulding gears by machinery mentioned in the report, can be used in bevel gear, worm gear, mitre and internal gear.

We can take very little credit for the building. We owe that to the The Variety Iron Works Co., and their Superintendent, Mr. Lewis, but as far as the shop work is concerned, I think we can do it with the improvements we have as well as it can be done in the country.

PRESIDENT:—I noticed that the ropes driving the main shafting were part slack and part straight, and I would like to know something of the philosophy of that.

Mr. WALKER:—The difference in the length of the two ropes, doing the same work, is a mystery to most people, and people generally think the slack rope is not doing any of the work, but it does its work just as effectually as the straight rope.

It is impossible to piece the ropes and have them the same length and it is impossible to keep them the same length. We have been compelled to stretch our ropes and possibly it will be of some interest to you to know that we take a piece of rope while it is new and stretch it with a 50 ton jack before it is put on the pulleys. It looks very odd to see the ropes so uneven.

We have been trying experiments with ropes and using half cotton and half hemp, and we find that hemp ropes keep round and wear smooth like an iron bar, while cotton wears fuzzy. The best thing I have known of to keep the particles of rope from wearing off is molasses and black lead.

PRESIDENT:—This has been a very interesting meeting. I hope more of our people will talk "shop" We need to know more of what shops and factories are really doing and not theorize so much.

A vote of thanks was tendered to Mr. Luther Allen of the Globe Iron Wks. Co., to the officers of the Ship Owner's Dry Dock Co, and to the officers of The Walker Manufacturing Co, for courtesies shown Members of the Club on the occasion of their recent visit to these works.

Mr E. P. Roberts then read an excellent paper on the Incandescent Electric Lamp from the stand-point of the Electric Light Manager, and of the Customer.

A large number of lamps of different candle power were shown, also the effects of different currents on the same lamp. He also exhibited a number of charts on which were curves showing the life of the lamp with different currents and the relative cost of lamps of different candle power. This was followed by a discussion, in which a number of Members participated.

Mr. W. P. Rice made a brief report of the Club's visit to The Globe Iron Works Co.'s shops and ship-yard.

The tellers reported that Mr. J. F. Holloway had been elected an Honorary Member, and that Messrs. Wm. H. Stair, Albert W. Johnston and Joseph C. Beardsley had been elected Active Members.

Prof. C. S. Howe then read a short paper on a New Method of Calculating Areas in land surveying, and showed that by using Crelle's multiplication tables, the method is fully as short as those in general use. This was followed by a brief discussion. Adjourned. A. H. PORTER, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

AUGUST 17TH, 1891.—An adjourned meeting was held at 8 p. m., at the office of Messrs. Sizer & Keerl, Atlas Building, Helena, Mr. W. A. Haven in the chair. There were present Messrs. Kenna, Foss, Lombard and Sizer. Mr. Sizer was elected Secretary pro tem.

The minutes of the previous meeting were read and approved.

The proceedings of meeting of General Committee of Engineering Societies on "International Engineering Congress and Engineering Headquarters," World's Columbian Exposition, 1893, were read, and the action of the Committee endorsed, and the Secretary instructed to so advise the Secretary of said Committee and to issue an order for $50, payable to the Treasurer of the General Committee. on account of the quota to be assessed this society.

The ballots on the Revised Constitution and By-Laws were canvassed. Ten votes were cast all in the affirmative, thus adopting the Revised Constitution and By-Laws.

The Secretary was instructed to have the Revised Constitution and By-Laws printed as soon as convenient.

Adjourned. F. L. SIZER, Secretary pro tem.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

DECEMBER 7, 1891:—A joint meeting of the Civil Engineers' Society of St. Paul and the Minneapolis Engineers' Club was held at the rooms of the former society Dec. 7. Prof. W. R. Hoag of Minneapolis read a paper on Geodetic Leveling, explaining the instruments employed, their adjustments and use. He stated that a precision of 1 to 1,000,000 common in horizontal is not possible in vertical measurements. One m m. into the square root of kms. run is precise for levels. Five m m. $\sqrt{\text{km}}$. is hardly passable. A portable turning point is used, the rod resting in a shallow cavity therein, and held as nearly plumb as practice enables a rodman to hold it. Readings are taken to 1/10 m.m.

The exercises of the evening were concluded in a dining room at the Windsor.

C. L. ANNAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

285TH MEETING, NOV. 4, 1891.—The 285th meeting of the Society was held at its rooms, Wednesday evening, November 4th, 1891, at 8 p. m. President L. E. Cooley in the chair and 85 members and visitors present.

The minutes of the previous meeting were approved, and there being nothing to report from the Board of Directors, the President called upon the Secretary to read the proposed Amendments to By-laws relating to the election of officers

The President next called for Reports of Committees.

MR. W. J. KARNER, Chairman of Committee on Badge, Seal, and Diploma suggested that the members of the Society be invited to send in designs for the three purposes of badge, seal and diploma, or suggestions to guide in the selection from designs sent in. or to aid the committee in making designs.

The Secretary was directed to not e the request in the minutes and draw special attention of the members to the matter.

The designs should be simple as possible, consistent with expressing all that may be desired and should be mailed or sent to Mr. W. J. Karner, 205 La Salle street, Chicago, if possible on or before November 25th.

MR. BENEZETTE WILLIAMS for Committee on the "Railroad Problem," etc., said the Committee's report was not yet ready. A great deal of work had been done upon it, but in the absence of quite a number of the members of the Committee no progress could be reported.

The President then called for the paper of the evening. "THE FOUNDATIONS

AND FLOORS FOR THE BUILDINGS OF THE COLUMBIAN EXPOSITION," by Mr. A. Gottlieb.

On the conclusion of the paper President Cooley said: We have listened to the paper of Mr. Gottlieb on the question of the foundations and the strength of the material used in the buildings of the World's Fair. I do not know whether you all can, I think I can, sympathize with his desire to keep professional matters out of the newspapers. This paper is a very important one. It deals with a subject which has excited some comment half way round the globe, in view of the widespread concern of the nation in the success of this enterprise at Chicago. The paper is valuable for the data which it contains. We have assembled here a large quantity of matter with a view to a special application, matter which it is usually difficult to get together and in which large elements of judgment are allowed in the profession, and the application of it is doubly interesting on account of the importance of the subject, and especially valuable to engineers who have to deal with the temporary uses of timber. I am very glad that the paper has been presented to the Society, and I hope it will be discussed at length, informally here and formally by contributions later.

Messrs. Benezette Williams, Sloan, Johnston, Purdy, Ostenfeldt, Cregier, Rossiter, Prussing, Herr, Goldmark, Gottlieb and the President participated in the discussion, which together with the paper is published in this issue of the JOURNAL.

Mr. Sloan moved a vote of thanks to Mr. Gottlieb for his interesting paper. Carried.

Adjourned.

JOHN W. WESTON, Sec.

INDEX DEPARTMENT.

ANNUAL SUMMARY.

It is proposed to furnish, in this department, as complete an Index as may be of current Engineering Literature of a fragmentary character. A short note will be appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. The Index will be mostly limited to society and magazine articles, and special engineering reports of general interest and value. It is printed in the monthly issues of the JOURNAL, *on but one side of the paper, so that the titles may be cut out and pasted on cards or in a book, and is here collected with additional cross references.*

LIST OF PERIODICALS INDEXED.

American Architect (Am. Arch.), weekly, Ticknor & Co., 211 Tremont street, Boston, Mass.; single copy, 15 cents.

American Engineer (Am. Engr.), weekly, Gaff Building, Chicago, Ill.; per year, $2.00; single copy, 5 cents.

American Journal of Railway Appliances (Am. Jour. Ry. Appli.), monthly, World Building, New York; per year, $2, single copy, 25 cnts.

Engineeiing (N. Y. Eng.), monthly, World Building, New York; per year, $3; singlecopy, 25 cents.

American Machinist (Am. Mach.), weekly, 93 Fulton street, New York; per year, $2.50, single copy, 5 cents.

American Manufacturer and Iron World (Am. Mfr.), weekly, Pittsburgh, Pa.; per year, $4; single copy, 10 cents.

Electrical Review (Elec. Rev.), weekly, 22 Paternoster Row, London, E. C.; per year, 21s. 8d.; single copy, 4d.

Engineering Record (Eng. Record), weekly, 277 Pearl street, New York, per year, $ 5 single copy, 12 cents.

Engineering News (Eng. News), weekly, Tribune Building, New York; per year, $5; single copy, 12 cents.

Engineering and Mining Journal (E. & M. Jour.), weekly, 27 Park Place, New York; per year, $4; single copy, 10 cents.

Engineering (Lon. Eng.), weekly, London, England; per year, $10; single copy, 25 cents.

Indian Engineering (Ind. Eng.), weekly, Calcutta, India; 78s. per year; single copy, 8 Annas.

Journal of the Franklin Institute (Jour. Fran. Inst.), monthly, Franklin Insitute, Philadelphia, Pa.; per year, $5; single copy, 50 cents.

Journal of the Association of Engineering Societies (Jour. Assn. Eng. Soc.), monthly, 78 La Salle street, Chicago; per year, $3; single copy, 30 cents.

Journal of the Society of Arts (Jour. Soc. Arts), weeklv, London, England; single copy, 6d.

Mechanics (Mechanics), monthly, 907 Arch Street, Philadelphia, Pa.; per year, $1; single copy, 10 cents.

Power (Power), monthly, 113 Liberty Street, New York; per year, $1; single copy, 10 cents.

Proceedings American Institute of Mining Engineers (Proc. A. I. M. E.), 13 Burling Slip, New York; per year, $5.

Proceedings of the United States Naval Institute (Proc. U. S. N. I.), quarterly, United States Naval Institute, Annapolis, Md.; per year, $3.50; single copy, $1.

Railroad and Engineering Journal (R. R. & Eng. Jour.), monthly, 45 Broadway, New York; per year, $3; single copy, 25 cents.

Railroad Gazette (R. R. Gaz.), weekly, 73 Broadway, New York; per year, $4.20; single copies, 10 cents.

Railway Review (Ry. Rev.), weekly, The Rookery, Chicago, Ill.; per year, $4.

Scientific American Supplement (Sci. Am. Sup.), weekly, 361 Broadway, New York; per year, $5; single copy, 10 cents.

Scientific American (Sci. Am.), weekly, 361 Broadway, N. Y., per year, $3.

Street Railway Review (St. Ry. Rev.), monthly, 334 Dearborn st., Chicago, Ill.; per year, $1; single copy, 15 cents.

Street Railway Journal (St. Ry. Jour.), monthly, World Building, New Y per year, $4; single copy, 35 cents.

The Newspaper Agency, 19 Spring Gardens, London, England.

The Electrical Engineer (Elec. Engr.), monthly, 11 Wall street, New York; per per year, $3; single copy, 10 cents.

The Electrical World (Elec. World), weekly, 177 Times building, New York; per year, $3; single copy, 10 cents.

The Engineer (Lond. Engineer), weekly, London, England; yer year, $10; single copy, 25 cents.

The Railway Master Mechanic (Mast. Mech.), monthly, "The Rookery," Chicago, Ill.; per year, $1; single copy, 10 cents.

The Mechanical World (Mech. World), weekly, Manchester, England; per year, 8s. 8d.; single copy, 1 penny.

The Street Railway Gazette (St. Ry. Gaz.), monthly, 8 Lakeside Building, Chicago; per year, $2; single copy, 25 cents.

Transactions American Society of Civil Engineers (Trans. A. S. C. E.), 127 East Twenty-third street, New York; per year, $10.

Transactions Canadian Society of Civil Engineers (Trans. Can. Soc. C. E.), Sec'y., McGill University, Montreal.

Transactions of the Technical Society of the Pacific Coast (Trans. Tech. Soc. Pac. C.) Rooms 14-15, 408 California street, San Francisco, Cal.

Age of Steel (Age of Steel), weekly, Equitable Building, St. Louis, Mo.; per year, $3.

Annales des Ponts et Chaussees (Annales des P. & C.), monthly, Vve. Ch. Dunod, 49 Quai des Augustins Paris. France.

Journal of the New England Water Works Association (Jour. N. E. W. W. Assn.), quarterly, 113 Devonshire St., Boston, Mass.; per year, $2; single copy, 75 cents.

Proceedings of the Engineers' Club of Philadelphia (Proc. Eng. Club Phila.) quarterly, 1122 Girard St., Philadelphia, Pa.; per year, $2.

Proceedings of the Institution of Civil Engineers (Proc. Inst. C. E.), 25 Great George St., Westminster, S. W. London, Eng.

Proceedings of the Society of Arts (Proc. Soc. Arts); Mass. Institute of Technology, Boston, Mass.

School of Mines Quarterly (Sch. Mines Quart.), Columbia College, New York City; per year, $2; single copy, 50 cents.

The Engineering Magazine (Eng. Mag.), monthly, World Building, New York; per year, $3; single copy, 25 cents.

The Railway Engineer (Ry. Eng.), monthly, 8 Catherine St., Strand, W. C., London, Eng.; single copy, 1 s.

The Locomotive (Locomotive), monthly, Hartford, Conn.; per year, 50 cents.

Transactions American Society of Mechanical Engineers (Trans. A. S. M. E.), 12 West 31st Street, New York.

Ammunition Cart. *Notes on Experimental.* Description of the cart designed for supplying infantry fighting line with ammunition. Two single-wheeled hand-carts make one two-wheeled horse-cart. Illus. *Proc. U. S. Naval Institute*, Vol. XVII, No. 1, 1891.

Aqueduct, *Croton; Notes on the Excavation of.* A valuable paper by J. P Carson describing the Geology of the section, methods of excavation, lighting and ventilation, and the methods used in the tunneling through some very bad ground. Fully illustrated. *Trans. A. I. M. E.*, 1890, pp. 56. Abstract from the portion relating to difficult tunneling in *E. & M., Jour.*, Apr. 25, 1891, pp. 494-6.

———, *Croton. Pumps and Methods used for Grouting.* A paper by P. F Brendlinger. *Proc. Engrs. Club of Phila.*, Dec. 1889, Vol. VII, pp. 241-5.

———. *Construction of the New Nadrai (Kali Nadi) Aqueduct, Ganges Canal.* Consists of 15 arches of 60 ft. span. Well-foundations with concrete filling. Folding plate of illustrations. By William Good. *Proc. Inst. C. E*, Vol. CV, 1891, pp. 147-60, Lon. *Eng.*, Oct. 23, 1891. *Ind. Eng.*, Oct. 17. 1891, (with inset).

Arches. See Viaduct, Fireproof Arches.

———, *Iron.* See Bridge.

———. *Stone Arch at Falls of Schuylkill; Philadelphia & Reading R. R.* 80 ft. span, with a rise of 26 ft. Segmental arch. Brief description with drawings. *Eng. News*, Jan. 24, 1891, p. 89.

———, *Stone Arch Highway Bridge Over the Turkey River, Elkader, Ia.* Description with plan, elevation, section, and general views of this two-span arch bridge. Spans. 84 ft. each, and 27.9 ft. rise. *Eng. News*, Apr. 11, 1891, pp. 338-9.

Arches. *Monier Method of Constructing.* In this the arch is built of concrete, and has wire netting imbedded in it, near the soffit. Account of the construction of such an arch, with tests imposed. Illus. *Eng. News*, May 23, 1891, pp. 499-500. From an article by F. Holzer, in *Wochenschrift des Oesterr. Ing. u Arch. Vereins.*

———. *Recent Construction in Germany of Masonry Arches with Joints at Crown and Point of Rupture.* Lead joints are inserted at these points. Description of the Method, with analysis of stresses, and application to four German bridges. Four folding plates. Paper by G. LaRiviere in *Annales des P. et C.*, June, 1891, pp. 899-949. Abstract, *Eng. News*, Oct. 24, 1891, pp. 378-80.

Architect, *Owner and Builder before the Law.* Several papers relating to contracts, architects, duties, powers, etc. *Am. Arch.*, Aug. 8, 1891, *et seq.*

Architecture *of the United States.* Three papers illustrating and discussing the different classes. By M. Brincourt in *Encylopedie de l' Architecture et de la Construction. Am. Arch.*, Nos. 812-14, July 18, 25 and Aug. 1, 1891.

———. See Engineering and Architecture, Stairways.

Armature Reactions. A Theoretical investigation by F. C. Wagner, in *the Technic.* Reprinted in *Elec. World*, Aug. 22, 1891, pp. 129-31.

Armor. *Modern Armor.* An article by F. R. Brainard, U. S. N, giving a brief description of the methods of manufacture, and chief requisites. Illus. *Sci. Am. Sup.*, No. 803, May 23, 1891, pp. 12829-30.

Armor Tests. Brief account of tests on deflective armor plates, July 24, 1891. *Eng. News.*, Aug. 1, 1891, p. 95.

———. *Competitive Trial of Armor Plates.* Report of Committee of Ordnance Dep't U. S. N., on firing test of three plates, respectively, of steel, nickel steel, and compounds. Illustrated fully by photographs. *Proc. U. S. Naval Institute.* Vol. XVI, No. 5, 1890.

———. *Comparative Trial of Steel and Steel—Faced Armor at St. Petersburg,* Description of tests on three plates Illustrated. Lon. *Engineer*, Nov. 21, 1890, pp. 409-12.

———. *Trial of American Heavy Armor Plate.* Partial results of trials of low and high carbon nickel-steel and Harvey steel. *R. R. Gaz.*, Nov. 6, 1891 pp. 780.

ed for the Engineering Laboratory of the Western Polytechnic Institute. Illus. *Mechanics*, July, 1891, pp. 157-8. *Am. Mach.*, July 9, 1891.

Blast Furnace. *Charges. Calculations of.* By A. Ledebur. Translated from *Handbuchder Eisenhuttenkunde*, *E. & M. Jour.*, Dec. 13, 1890, pp. 692-4.

Blast-Furnaces *American Blast-Furnace Practice.* A discussion suggested by the paper of Mr. James Gayley on "The Devclopment of American Blast-Furnaces," *Trans. A. I. M. E., XIX, 952*. *Trans. A, I. M. E.*, 1891, pp. 26.

———. *Some Experiences on Blast-Furnace Gases.* Paper by Jasper Whiting, giving results of a continuous series of analyses extending over several days. Curves showing variation drawn. *Trans, A. I. M, E.*, 1891, pp. 11.

Blast-Furnaces. *Hoist for.* See Hoist.

Block Signaling. See Railroad Signaling.

Blowing Engine. See Engine.

Blue Printing. *Rapid Blue Printing Paper.* Solutions giving a more rapid printing paper and better prints. *Eng. News*, May 23, 1891, p. 486.

Boat. Full description of the U. S. Lighthouse Tender Azalia. Illustrations of the compound engines, etc. *Iron Age*, Dec. 11, 1890, pp. 1029-34.

Boat Railway. *The Proposed Boat Railway Around the Dalles Rapids of the Columbia River.* General description of the project with extracts from the report of the U. S. Engrs., giving details of car and hydraulic lifts, capacity and estimate of cost. Inset of details. *Eng. News*, Sept. 12, 1891, pp. 228-31.

Boiler Explosions. *The Cause of Boiler Explosions*. Diagram showing causes of 1,076 boiler explosions classified under fifteen heads. *The Locomotive*. Sept. 1891.

Boiler Furnaces. *Experiments on the Use of Steam Jets for Producing Forced Draught in Boiler Furnaces*. Tests made at the N. Y. Navy Yard. Results with illustrations of nozzles used. *Eng. News*, Sept. 19, 1891, pp. 266-7.

Boiler Testing. *Heating Feed-Water With Live Steam.* Account of a test showing a remarkable gain in economy by this method of heating. Lon. *Engineer*, July 3, 1891. Reprinted in *Eng. News*, July 25, 1891, pp. 82-3.

———. *Hydraulic Tests.* A brief article discussing the value of such tests, reprinted from the *Practical Engineer*, (Lon.). *Am. Engr.*, Dec. 13, 1890, pp. 258-9.

———. *Tests of Coil Boilers for the U. S. Navy*. Description with account of test of a Ward coil boiler. Also a discussion of the advantages of this type of boiler. Illus. *Eng. News*, Aug. 29, 1891, pp. 184-5.

Boiler Tubes. *Tests of the Serve Ribbed Boiler Tubes.* Results of tests made with both forced and natural draught, show a remarkable gain in economy of fuel and capacity of boiler. Tests were made on a vertical tubular boiler, *Eng. News*, May 9, 1891. p. 442. Abstract *R. R. Gaz.*, May 8, 1891, p. 320; *Ry. Rev.*, May 9, 1891, p. 302.

Boilers. *Application of Zinc in Boilers.* A paper by Mr. John Green read before the Inst. of Marine Engrs., discussing the use of zinc to prevent corrosion, and giving several cases from practice. with discussion. *Iron*, March 27, 1891, pp. 267-70. *Am. Eng.*, Apr. 18, 1891, pp. 157-9.

———. *Circulation of Water in Steam Boilers.* Extracts from a lecture by Mr. G. H. Babcock before the students of Cornell University, discussing and illustrating this question. *Eng. Record*, May 16, 1891. pp. 397-8.

———. *Construction of Boilers Adapted to Forced Draught.* A paper by A. F. Yarrow, read before the Inst. of Naval Architects, discussing mainly the problem of avoiding leaky tubes. Illustrated. *Ry. Rev.*, April 4. 1891, pp. 222-3, *et seq.* Lon. *Eng.*, March 20, 1891, pp. 335-9. Lon. *Engineer*, March 20, 1891, pp. 225-8.

———. *The Danger of Employing Certain Disincrusting Agents in Small Boilers.* Full account of two explosions due to this cause. Details illustrated. By ——— Orly. *Annales des Ponts et Chaussees*, March, 1861, pp. 434-42.

sion. Also a discussion of this subject at a meeting of the Central Railway Club. *R. R. Gaz.*, Apr., 17, 1890, pp. 261-3. *Eng. News.* Apr. 18, 1891. pp. 379-80. Abstracts. *Ry. Rev.*, Apr. 18, 1891. *Mast. Mech.*, May, 1891.

————. *Air Brakes in Freight Service.* A paper by G. W. Rhodes before the Western Ry. Club, giving a discussion of the new M. C. B. Rules. Abstract, *R. R. Gaz.*, Oct. 10. 1891, pp. 707-11.

————. *Equipment of Freight Cars with the Westinghouse Automatic Brake.* Map showing progress of this improvement. with statistics from the various railroads. *Eng. News*, May 2, 1891, pp. 430-1. Editorial discussion, pp. 425-6.

————. See Car Couplers.

Brick. *Experiments on the Permeability of.* A paper by A. W. Hale, Asst. Engr. New Croton Aqueduct, giving methods of testing and results. Illus. *Eng. News*, Jan. 3, 10, 1891.

————. *Paving Brick.* Record of some tests made by Mr. E. Butts, City Engr. Kansas City, on crushing strength, absorption, and abrasion. Results plotted. *Eng. News*, Apr. 11, 1811, p. 352. *Eng. News.* May 2, 1891, p. 367.

Brick Pavements. See Pavements.

————. *Paving Brick and Brick Pavements.* A paper of some value, by C. P. Chase, State Univ. of Iowa. *The Transit*, Dec. 1890, pp. 79-98.

Bricks. *Slag Brick Manufacturers in Montana.* Description and illustration of a simple apparatus. By Thos. Egleston. *School of Mines Quart.*, Apr., 1891, Vol. XII, pp. 189-93. *Eng. Record*, June 13, 1891, pp. 29-30. Brief notice in *Eng. News*, June 20, 1891, p. 601.

Bridge. *Brazilian-British American Bridge.* Designed by an English engineer after an American type. Contains several peculiar details. Illustrated description, also editorial discussion of the design. *Eng. News*, July 25, 1891, pp. 79-80, 83-84.

————. *Brooklyn, New Terminals for.* Report of the Board of Experts. *Eng, News*, Jan. 17, 1891, pp. 54-5. *Eng. Record*, Jan. 17, 1891, pp. 105-6. *R. R. Gaz.*, Jan. 16, 1891, p. 42. *Ry. Rev.*, Jan. 24, 1891, pp. 54-5.

————. *Cairo Bridge, Substructure of.* Abstract of Mr. E. H. Connor's paper published in the *Jour. Assn. Eng. Soc.* The foundations are described and an inset plate gives illustrations of piers, and details of caissons and sand pump. *Eng. News*, Feb 7, 1891, pp. 122-4.

————. *Cedar Avenue Bridge—Baltimore, Md.* A braced arch of 150 ft. span. General view and page of details. *R. R. Gaz.*, Sept. 18, 1891, pp. 649-51.

————. *Chittravati Bridge.* A paper by E. W. Stoney, giving an account of the construction of this large bridge, including the sinking of eighteen cylinder piers. 2 plates. *Proc. Inst., C. E.*, Vol. CIII, 1891, pp. 135-50 Discussion and correspondence, pp. 151-200.

————. *Clarence Bridge at Cardiff.* A steel structure of 464 ft. long with a 190 ft. draw span. Details of superstructure, caissons, and fenders are given with a general description of the bridge. Lon. *Eng.*, Feb. 13, 1891, pp. 15-88, *et seq.*

————. *Coteau. The Swing Span and Pivot Pier of the Coteau Bridge. Method of Floating Spans into Place.* Illustrated description with inset showing details of machinery for operating. *Eng. News*, May 30, 1891, pp. 524-5.

————. *Driving Park Avenue Bridge, Rochester, N. Y.* A three-hinged iron arch of 428 ft. span. Full description with detail drawing. *Eng. Record*, July 18, 1891, *et seq.* Brief description, *R. R. Gaz.*, July 17, 1891, pp. 492-3.

————. *Experiments Upon an Iron Bridge of 35 Meters Span.* Paper by M. Cuenot. The bridge, a riveted Warren girder, was subjected to various loadings, both stationary and moving, and the resulting stresses obtained by measurement of elongations and compressions of the various members. The stresses due to a moving load were about 20 per cent. greater than those due to the same stationary load. *Annales des P. et C.*, July, 1891, pp. 5-36.

S. Morison, Chief Eng. Illus. *R. R. and Eng. Jour.*, May, 1891, pp. 219-22.

————. *St. Louis Merchants Bridge*, Description, details, and general specifications, Lon. *Eng.*, June 5, 1891, pp. 686-7, *et seq.*

————. *Susquehanna River Bridge at Harrisburg, Pa.* Brief description wtth illustration of coffer dam and diagram showing the system of triangulation used for locating the piers. *R. R. Gaz.*, Feb. 13, 1891, pp. 108-9.

————. *Swing Bridge Over the Glamorganshire Canal.* Fully illustrated description of a highway swing bridge. Entire weight rests on the pivot. Designed by Max am Ende. Lon. *Engineer*, Aug. 7, 1891. pp. 105-7.

————. *Walnut St. Bridge at Chattanooga, Tenn.* A 5-span iron and steel bridge over the Tennessee river. Description with folding inset showing elevation, design of masonry, strain sheets and details of superstructure. *Eng. News*, May 16, 1891. pp. 462-3.

————. *Washington Bridge Over the Harlem, New York City, Designs Submitted for.* (With inset.) Abstracted from the "History of the Washington bridge," by W. R. Hutton, Chief Engr., *Eng. News*, Dec. 27, 1890, p. 564.

————. *Winona Bridge, Swing Span of.* Brief description of the entire structure; with details of trusses and turning and lifting machinery of the swing span illustrated. Specifications as to quality of steel also given. *Eng. News*, Oct. 17, 1891, p. 370.

Bridge. See Canal, Viaducts, Truss, Girder, Arch, Drawbridges.

Bridge Accident. *The Moenchenstein Bridge Disaster.* Full account of this disaster with illustrations of various details of the bridge. *Eng News*, Aug. 1, 1891. pp. 90-4. *R. R. Gaz.*, July 17, 1891, pp. 496-9. Brief account, *Eng. Record*, July 25, 1891, p. 119.

Bridge Computations. See Roof and Bridge Trusses.

Bridge Designing. *French Pier Masonry and Bridge Detail.* Details of piers, and arch decorations of the bridge over the Rhone at Lyons. From *Le Genie Civil.* *Eng. News*, Sept. 5, 1891, pp. 220-1.

Bridge Designs. A paper by H. J. Lewis before the Eng. Soc. West. Penn., discussing briefly the designing of the various parts. With discussion. *Eng. News*, Oct. 17, 1891, pp. 367-9.

Bridge Details. *Chicago, Kansas City & Texas R. R.* The connections are designed with especial care in reference to avoiding difficult shop work, thus commanding a mimimum pound price. Inset showing details. *Eng. News*, Jan. 24, 1891, p. 87.

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